Sky and TELESCOPE

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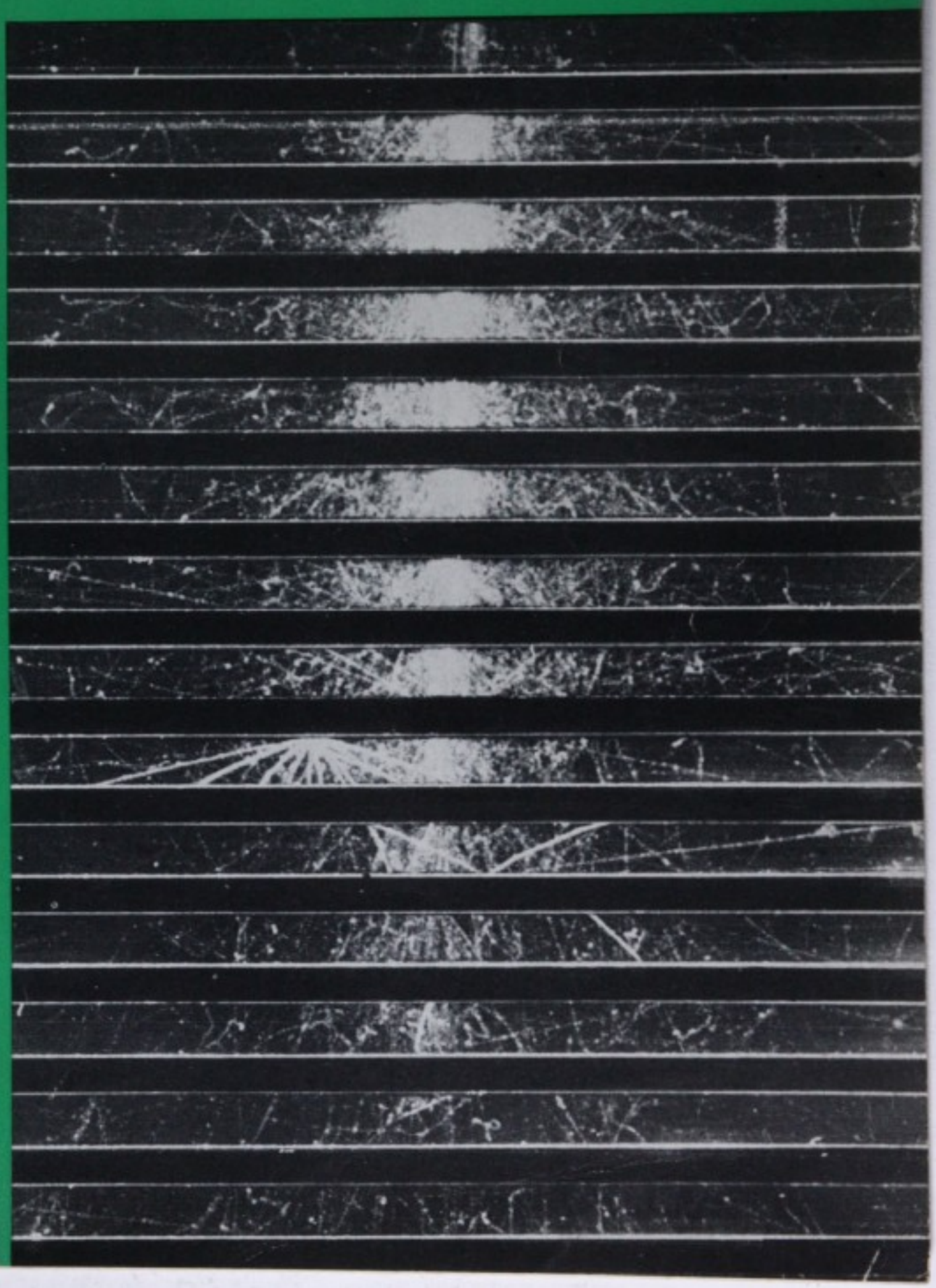

Cosmic ray shower

Time, calendar date, and year are shown for Earth and Mars in the Levitt-Mentzer clock. The numbers around the face indicate Mars time, and the three smaller dials (here arbitrarily set) register Martian date, terrestrial time, and terrestrial date. The clock, which is 16 by 16 by 14 inches in size, can also be run at over 2,000 times its normal rate to serve as a computing device for time-conversion problems.

Mars Clock and Calendar

By I. M. Levitt
Fels Planetarium
The Franklin Institute

ONE of the first pieces of scientific apparatus that the world's future pioneers into outer space will require is a timepiece that accurately records the 24 hours of the earth's day, and which may be instantly compared with time established for a planet, such as Mars, that may be the object of exploration. Even the return to Earth will probably have to be started at a precise hour, minute, and second of earth time, in order to rendezvous with an earth-satellite station.

The construction of a chronometer that ties together the time on the earth and on Mars is necessarily complicated, because of the difference in rotation periods for these two planets. The earth turns once in 23 hours, 56 minutes, and four seconds, which we call the sidereal day. However, the day we normally use is the mean solar day of 24 hours by our clocks. Mars rotates more slowly than the earth — its sidereal day is 24 hours, 37 minutes, and 23 seconds. Its solar day is about 2.7 per cent longer than the solar day on earth.

The Hamilton space clock illustrated here was constructed from the writer's design by Ralph B. Mentzer, assistant director of the process development laboratory of the Hamilton Watch Company. To correlate the Martian day, month, and year with our own, computations were based on Lowell's rotation period of 24 hours, 37 minutes, 22.58 seconds, for Mars. Since this work was done, Joseph Ashbrook has presented evidence that Lowell's period is 0.088 second too short. The figures in this article have been amended from those originally announced to correspond with the new value for Mars' rotation.

The large dial on the clock indicates Martian time, and is connected by gears to the small, lower dial indicating Greenwich civil or Universal time on earth. The earth pointer makes one full revolution in 24 hours, but the Martian pointer requires 39.6 minutes longer.

Since Mars is about 1½ times as far from the sun as the earth, its year is nearly twice as long. Mars requires 686.9797 earth days or 668.5991 Mars days to swing around the sun once. Our two simultaneous calendars have been set to begin with the Julian Day epoch, January 1, 4713 B.C. This date is selected as the start of Martian year 0. Using the 668.6-day year for Mars brings January 1, 1954, into the year 3641 M.Y. (Mars Year) on this Martian calendar.

On the clock, two similar dials show the year, month, and day, one for each planet. The Martian year has been arbitrarily divided into 12 months, eight of 56 days and four of 55 days, bearing the same names as those on the earth, but distinguished by a subscript letter "m." These months have days numbered up to 56, instead of to a maximum of 31. The four quarters are equal; the first and second months of each quarter have 56 days and the third has 55.

As the week is also arbitrary (both on the earth and Mars), with no relation to astronomical events, we may use a seven-day week for Mars, where it fits a convenient eight times into the 56-day months. But it is troublesome there, too, for some months are only 55 days long; thus, just as in the case of our own present calendar, the week does not fit into the year exactly. In our proposed calendar, however, the last Saturday of

BASIC DATA FOR A MARS CLOCK

Sidereal period of Mars	=	686.9797 solar days.
The Martian sidereal day	=	$24^h\ 37^m\ 22^s.6679$ in mean solar units,
	=	1.02595680 solar days.
686.9797 ÷ 1.02595680	=	669.599051 Martian sidereal days,
	=	668.599051 Martian solar days.
One Martian solar day	=	1 + 1/668.599051 Martian sidereal days.
The excess of the Martian solar day over its sidereal day is		
1.02595680 ÷ 668.599051	=	$2^m\ 12^s.5791$ in mean solar units.
The Martian solar day	=	$24^h\ 39^m\ 35^s.2470$ mean solar units.

each 55-day month is omitted, thereby keeping the weeks in step with the months throughout the year.

Mars has seasons very much like the earth's, because its axis is tipped away from the pole of its orbit about 25 degrees, corresponding closely to the 23½-degree angle for the earth's axis. Therefore, the sun appears to move north and south in the Martian sky during the planet's revolution around the sun. Each season is, of course, nearly twice as long as are ours.

It is with the seasons that a calendar must keep step. To produce on Mars what corresponds to the earth's tropical year, it is necessary to include 0.6 day at the end of the year. This interval corresponds to the extra quarter day of our years, which we take care of at four-year intervals by inserting a leap day. On Mars, we propose adding a day every three out of five years — the first and fourth years to contain 668 days, the other three years 669 days, and in these longer years December is given the extra day.

Just as the simple leap year rule is not enough for the earth, and the Gregorian calendar correction has to be added, so on Mars there is still 0.00095 day per year to account for. Therefore, each tenth century year, for instance, 4000, 5000, M. Y., will not be a leap year, in order to lose a day. After these adjustments, the Martian calendar will be in error by only one day in 20,000 years. This accuracy far surpasses our own Gregorian calendar, which is out one day every 3,000 years.

Built by Mr. Mentzer in his home workshop, the clock has almost 400 working parts. The basic motive power is a laboratory-type heavy-duty synchronous motor, 60 cycle, which provides sufficient power for a "time flyer." The device permits accelerating the clock by any amount to more than 2,000 times the clock's normal rate. This is achieved through an overhead-running clutch to bring into operation a high-speed aircraft-type geared-head series motor which is manually controlled by a variable transformer.

The experimental clock is really a computing mechanism, and can be used for demonstration purposes. A full 24-hour earth day can be observed in 45 seconds. The month and year indicators are 35-mm. film bands. We have projected the clock into the future, and its film strips indicate the course of time for a 20-year interval, January 1, 1970, to December 31, 1989, earth dates.

MARTIAN CALENDAR DATA

January 1, 1954, is 2,434,743.5 solar days after January 1, 4713 B. C., Greenwich noon. Since 2,434,743.5 ÷ 668.599051 is 3641.5+, January 1, 1954, falls in the Martian year 3641.

We adopt 668.6 for the number of Martian solar days in the Mars calendar year. Let two years out of every five be ordinary years of 668 days; the others will have 669 days. The calendar year is too long by 0.6 − 0.599051, which is 0.000949 day per year. This means that the calendar year will be out one day in about 1,000 years. Therefore, drop one day every 10th century.

Then the calendar year is 0.001 − 0.000949, or 0.000051 day too long, but the error amounts to only one day in 20,000 years.

A Calendar for Mars

JANUARY

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31	32	33	34	35
36	37	38	39	40	41	42
43	44	45	46	47	48	49
50	51	52	53	54	55	56

FEBRUARY

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31	32	33	34	35
36	37	38	39	40	41	42
43	44	45	46	47	48	49
50	51	52	53	54	55	56

MARCH

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31	32	33	34	35
36	37	38	39	40	41	42
43	44	45	46	47	48	49
50	51	52	53	54	55	

APRIL

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31	32	33	34	35
36	37	38	39	40	41	42
43	44	45	46	47	48	49
50	51	52	53	54	55	56

MAY

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31	32	33	34	35
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JUNE

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
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29	30	31	32	33	34	35
36	37	38	39	40	41	42
43	44	45	46	47	48	49
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JULY

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31	32	33	34	35
36	37	38	39	40	41	42
43	44	45	46	47	48	49
50	51	52	53	54	55	56

AUGUST

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31	32	33	34	35
36	37	38	39	40	41	42
43	44	45	46	47	48	49
50	51	52	53	54	55	56

SEPTEMBER

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31	32	33	34	35
36	37	38	39	40	41	42
43	44	45	46	47	48	49
50	51	52	53	54	55	

OCTOBER

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31	32	33	34	35
36	37	38	39	40	41	42
43	44	45	46	47	48	49
50	51	52	53	54	55	56

NOVEMBER

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31	32	33	34	35
36	37	38	39	40	41	42
43	44	45	46	47	48	49
50	51	52	53	54	55	56

DECEMBER

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31	32	33	34	35
36	37	38	39	40	41	42
43	44	45	46	47	48	49
50	51	52	53	54	55	

SPACE TRAVEL SYMPOSIUM

Arthur C. Clarke has been made coordinator of the Hayden Planetarium's third symposium on space travel, to be held in New York on May 4th. Speakers will include a number of authorities on rocket development, astronautics, and allied subjects. Mr. Clarke is a former chairman of the British Interplanetary Society.

NEW ASTRONAUTICAL SOCIETY

The American Astronautical Society was recently organized in New York City to promote the achievement of space travel, and to disseminate information for scientists and the public. The first open meeting was held at the American Museum of Natural History on March 19th, when Oscar Schachter, of the United Nations, spoke on the legal aspects of space travel, and the film Destination Moon was shown. A 1902 film, A Trip to the Moon, a short French satire, proved very amusing to the nearly 1,000 persons in attendance. It was lent by the Museum of Modern Art from its library of old and rare films.

The society plans to publish a journal, and expects to form chapters in major cities as membership warrants. Dues are $10.00 a year for ordinary members, who require no special qualifications; student membership, for those under 18, costs $5.00 per year. Additional information can be obtained by writing to the society at 516 Fifth Ave., New York 36, N. Y.

5-INCH FECKER-ROSS ASTROGRAPH

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Sky and TELESCOPE

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AIR FORCE AND OTHER EXPEDITION PLANS

A COMPREHENSIVE program of eclipse observations for geodetic purposes is being undertaken for the June 30th eclipse under sponsorship of the Air Force Cambridge Research Center and co-operating agencies. There will not be another total eclipse whose path adequately spans North America and Europe until June 14, 2151, so that the principal purpose of the observations will be accurate measurement of the distance between these two continents.

There will be four major and eight minor sites, the latter on the edges of the path of totality. Camps are to be established near James Bay; at Knob Lake, Que.; the Okak Islands, off Labrador; Greenland; the Faeroe Islands; the Shetland Islands; Norway; Sweden; and Iran. American scientists will be responsible for all programs, except in Norway and Sweden, where actual operations will be conducted by Finnish and Swedish scientists, and only a few American observers will be present.

Three methods of eclipse observing (named for the scientists who developed them) will be used simultaneously for the first time at four major sites, James Bay, Knob Lake, the Okak Islands, and in Iran. In the Bonsdorff method, motion pictures are taken of the crescent just before and just after totality to furnish precise contact times. The Lindblad method uses a motion picture record of the spectrum of the solar crescent, and the instants when the flash spectrum appears and disappears furnish the times of second and third contact, respectively. Gaviola's method is used to determine the time of mid-eclipse from a continuous photoelectric recording of the intensity of the sun's light.

Dr. W. A. Heiskanen, of Ohio State University, is supervising the Bonsdorff and Lindblad methods, assisted by Dr. T. J. Kukkamaki, Finnish geodesist, and Dr. J. Allen Hynek, Ohio State astronomer. Dr. F. J. Heyden, S.J., of Georgetown University, will supervise all observations with the Gaviola method, which he used in Africa in 1952. He will also have over-all charge of the eclipse station in Iran. Dr. Kukkamaki will be in charge of work at a post in Greenland, and Dr. Hynek will head the Ohio State party that goes to Iran.

Among the group at Iran will be Dr. Arne Slettebak, of Perkins Observatory. The Knob Lake station will be directed by Frederick Doyle, of Ohio State, and another Perkins astronomer, P. C. Stanger, will be part of this group. Leader of the Shetland Islands station will be Dr. Peter van de Kamp, of Sproul Observatory, with two other Swarthmore College astronomers in his party.

Edward A. Halbach, of the Milwaukee Astronomical Society, will lead the group going to the Okak Islands. Four members of the Amateur Astronomers Association of Pittsburgh, Adam L. Ott, Jr., Jay F. Kunze, Robert Kemper, and Robert Scherer, will be members of the party going to Labrador.

At the Geophysics Research Directorate of the Cambridge Research Center, the entire project is being organized by Capt. Ralph J. Ford. Co-operating agencies include the American Geographical Society, New York City; Georgetown University, Washington, D. C.; Ohio State University, Columbus, Ohio; and the Ernst Norrman Laboratories, Williams Bay, Wis.

Dr. George Van Biesbroeck, of Yerkes Observatory, will head an expedition sponsored by the National Geographic Society to observe the zodiacal light during totality on June 30th. Three stations will be occupied along a line extending from North Platte, Nebr., into eastern Colorado. At these points, where the sun will be totally eclipsed just before it rises, it is hoped that the sky will be darkened enough to permit observations of the inner zodiacal light, as explained by Drs. F. E. Roach and Van Biesbroeck in the March issue. Photoelectric scanners will make rapid

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COVER: A large shower of penetrating and cascade particles resulting from a cosmic ray encounter a short distance above the cloud chamber is shown here. The 14 lead plates are each 1.3 centimeters thick. In the uppermost section is a small collimated group of high-energy particles that cause the release of energetic particles forming the cascade. With a range of about 12 centimeters of lead, and with possibly about 100 particles at its maximum growth, the cascade must have had an original energy of about 10 billion electron volts. Note the striking display of heavily ionizing (lower energy) particles that spread out from the lower surface of the eighth plate, to the left of the main cascade. Photograph by William B. Fretter, University of California at Berkeley, with permission of the **American Journal of Physics**; caption material is from **Cloud Chamber Photographs of the Cosmic Radiation**, by Rochester and Wilson, Pergamon Press, Ltd. (See page 222.)

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American Astronomers Report

Here are highlights of some papers presented at the 90th meeting of the American Astronomical Society at Nashville, Tenn., in December. Complete abstracts will appear in the Astronomical Journal.

The Behavior of Matter in Space

The two main questions considered by Dr. Lyman Spitzer, Jr., Princeton University Observatory, who gave the seventh Henry Norris Russell lecture, were: What determines the temperature of the interstellar gas? How can we explain the random motions of the interstellar clouds?

What we mean by the temperature of interstellar space depends on the "thermometer" we use and on our definition of temperature. A black body, heated by starlight, will be at the very low temperature of only three degrees above absolute zero, when located far from any particular star; but in these same regions the energies of cosmic ray particles correspond to trillions of degrees.

Dr. Spitzer adopted the principle that most of the atoms in the interstellar gas have random velocities which can be expressed in terms of the temperature of a gas in the ordinary sense. That is, the distribution of the velocities in the interstellar gas can be shown to be Maxwellian, analogous to how molecular velocities are distributed for a sample of air in thermal equilibrium. This condition holds certainly for those hot regions where the hydrogen is ionized (H-II regions), for un-ionized (H-I) regions in general, and also for dust grains.

The temperature of the gas depends upon the balance between the absorption of energy from starlight and the radiation of this energy by the gas. Eddington pointed out many years ago that interstellar gas can gain heat from starlight by the photoelectric effect. An atom is first made neutral (if it were ionized previously) by capturing an electron; then a stellar photon of high energy strikes the neutral atom and is absorbed; its energy is acquired by the electron which escapes with more energy than it had before it was captured. The additional kinetic energy is thus available for heating the gas. Most of the heating by this process must occur in the H-II regions near hot stars, for the ultraviolet radiation capable of ionizing hydrogen or helium is available only around such stars.

In the cooling of the gas, however, atomic hydrogen plays a very minor role, because this atom is a very poor radiator in visible and infrared light. The dominant process is excitation of an atom by electron impact, followed by radiation of a photon of light, which carries away into space the energy lost to the atom by the colliding electron. Atomic hydrogen cannot radiate under such electron bombardment unless the electrons have some 10 volts of energy, corresponding to a temperature well above 10,000° absolute. Most other atoms, however, have excitation potentials from a hundredth of an electron volt to several electron volts, and they can be important in the cooling process.

From cross-sections for excitation of the oxygen atom, recently computed by Seaton, Dr. Spitzer finds of great importance the 3.31-electron-volts excitation of ionized oxygen. After a wait of several hours, an atom excited in this way will emit a photon of the forbidden line at wave length 3727 angstroms. If there is an appreciable amount of singly ionized oxygen present in H-II regions, the equilibrium temperature would appear to be about 10,000° K. There is, however, a possibility that ionized nitrogen might play a similar cooling role, but this does not seem very probable in view of the considerable observed strength of the interstellar 3727 line.

The situation in the H-I regions differs because the chief heating mechanism, absorption of ultraviolet light by hydrogen atoms, is not operative. The cooling processes are again dependent on low excitation potentials, and several kinds of atoms may take part. There may be a slight heating of neutral hydrogen by the impact of cosmic ray particles, but this is uncertain. Interstellar grains tend to lower the temperature, as neutral hydrogen atoms lose energy on collision with them. The presence of hydrogen molecules would afford very efficient cooling if any effect, such as the passage of a shock wave, were to cause a temperature rise. The combined effect of all these processes, while difficult to work out in detail, must lead to a temperature of the H-I regions of about 50° absolute.

In principle the temperature of neutral hydrogen clouds can be found from the intensity of the hydrogen 21-cm. line, if an observed cloud is opaque at this wave length. The first preliminary measures do confirm low temperatures; this is an important field for further work.

The interstellar gas, besides sharing in the rotation of the galaxy, has also turbulent motions; the clouds have velocities averaging about five to 10 kilometers per second, but occasionally motions of 100 kilometers per second are

This picture of the region of Orion's belt was made October 3, 1948, by John C. Duncan with the 18-inch Palomar Schmidt camera. The three belt stars extend to the upper right, and the Great Nebula in Orion's sword is partially included in the lower right. Near the center of the field, Zeta Orionis is immersed in bright nebulosity. The lower of two tongues of dark matter silhouetted against this nebulosity is the famous Horsehead nebula. Mount Wilson and Palomar Observatories photograph.

Observed Characteristics of Interstellar Matter

HYDROGEN GAS

Density. About 1 atom/cm.^{3} in spiral arms, with much lower values outside the arms.

Physical State. Ionization nearly complete within 20-150 parsecs of *B* and *O* stars (H-II regions). Elsewhere predominantly neutral (H-I regions). Temperature greater than 1,000° K. in H-II regions; about 50° K. in dense H-I clouds.

Velocities. Circular velocity of galactic rotation; turbulence between 5 and 10 km./sec. (root mean square of radial velocity).

OTHER ELEMENTS IN GAS

Density. Mean density of neutral sodium and ionized calcium about 3×10^{-9} atoms/cm.^{3}. Fe, Ti, K, CH, CH+, CN present with about the same density.

Velocities. Most clouds move with local circular velocity of galactic rotation, plus r.m.s. spread of 5 to 10 km./sec. in radial velocity. About 1% have high random velocities, from 25 up to 95 km./sec.

Distribution. Straight line in galactic plane near sun intersects 10 such clouds per kiloparsec. Ionized calcium present in clouds or currents of differing velocities, but its ratio to sodium is greater in high-velocity than in low-velocity clouds.

GRAINS

Size. Mean radius of optically important grains is about 3×10^{-5} cm. Distribution of radii very similar in different regions.

Density. Mean space density of optically important particles in local spiral arms is about 10^{-26} gm./cm.^{3}; density is much less outside spiral arms.

Distribution. Spatial distribution is extremely irregular; concentrations ranging from 0.05 to 50 parsecs, with density varying by at least 10^4.

Polarization. Grains are somewhat elongated, and tend to be oriented perpendicular to local spiral arms.

observed. Collisions between clouds are frequent—about once in 10 million years for any one cloud. As the collisions are inelastic, the motions would die out quickly unless sustained by temperature differences between various parts of the gas.

High-temperature regions should expand at the expense of low-temperature regions, until pressure equilibrium is attained, when the neutral hydrogen regions would have roughly 200 times the density of the ionized regions, since this is about the ratio of probable temperatures. The density of hydrogen in an H-I cloud is probably about 10 atoms per cubic centimeter, but in the spaces between the interstellar clouds the density is probably less by a factor of 100 or more.

Thermal effects that produce motions in interstellar matter may include heating by an early-type star—this might cause heated gas to rise away from the galactic plane, buoyed up by heavier gas. J. H. Oort has suggested that when a star is formed by condensation within a cloud the rapid increase in radiation pressure as the star begins to shine might cause a violent explosion of the cloud.

Small clouds near which a very hot star passes may be accelerated to very high velocities by what Dr. Spitzer called "the interstellar rocket." The star's radiation would heat one side of the dense cloud, causing the heated material to expand toward the star; the recoil from this expansion would accelerate the remainder of the cloud away from the star. In this way a cloud, initially nearly stationary with respect to the star, could by the sacrifice of 99 per cent of its mass be accelerated to a speed of 80 kilometers per second.

Dr. Spitzer regards all of these processes as likely to occur, with Oort's mechanism of an explosion around a newborn *O* star accounting for the bulk of cloud motions.

The expansion of a rarefied hot cloud into a denser medium is an unstable situation, and Frieman and others have shown theoretically that thin spikes of cooler, denser hydrogen gas should project into the hotter and rarer expanding gas. This appears to explain what is frequently observed in emission nebulae, such as the Horsehead in Orion and M16 in Serpens: tongues or "elephant trunks" of obscuring matter extending inward from surrounding dark nebulosity and pointing toward the exciting star or stars.

The effect of an interstellar magnetic field upon cloud motions must also be considered. Field and motions must be intimately connected, since under the conditions in interstellar space ionized particles cannot stray very far from a particular line of force. The field, if it is strong, will restrain the motions of the clouds, or if it is weak will be distorted by them. Homogeneous magnetic fields have been proposed by several investigators to explain the polarization of starlight.

Dr. Spitzer thinks that a homogeneous field in the galaxy is improbable; he believes it is probably locally chaotic with an average tendency for the lines of force to lie parallel to the spiral arms. Such a chaotic field would fit better the observed randomness of the motions of the interstellar clouds.

Rotating Magnetic Stars and Cosmic Rays

The possibility that cosmic rays may originate from rotating stars with strong magnetic fields was suggested by Dr. Armin J. Deutsch, Mount Wilson and Palomar Observatories. Such stars, recognizable from their conspicuous periodic spectral changes, constitute about 10 per cent of the *A* stars with peculiar spectra.

On this hypothesis, an atom of interstellar gas, if it could approach to within about 10 radii of such a star without acquiring its rotational velocity, would be ionized, and then the ions would rapidly acquire tremendous energies from the magnetic and electric fields of the star. For instance, the proton and electron of an ionized hydrogen atom would in six seconds of time acquire over 10^{10} electron volts each in moving a distance of one stellar radius along the lines of force.

Some of these energetic particles might move down the lines of force and strike the star's atmosphere, perhaps initiating cascade processes that would lead to the observed abundance anomalies for the peculiar *A* stars. Other particles, on moving out into space, might be further accelerated by the magnetic field of the galaxy, as E. Fermi has suggested, to become primary cosmic ray particles.

Dr. Deutsch's proposal is tentative, and encounters several serious obstacles. Thus he points out that unless the density of interstellar matter near the *A* star is less than 1/1,000 atom per cubic centimeter, this matter would be so highly conducting that the energizing of the newly formed ions would be inhibited. It is at present a critical question whether or not the density a few radii above the surface of an *A* star is this low.

Nova Tucanae 1952

An addition to the short list of novae that have appeared in the Small Magellanic Cloud was reported by Henry J. Smith, of the Harvard Observatory's station at Bloemfontein, South Africa. The nova was recognized by its spectrum on an objective-prism photograph taken with the ADH Baker-Schmidt telescope on December 21-22, 1952. On this plate the spectrum greatly resembles that of Nova Herculis 1934 nine days before that star's maximum.

Direct photographs show that Nova Tucanae reached maximum on December 19-20, 1952, fluctuating rapidly between magnitudes 11.0 and 11.5 on that night. During the next nine months the object faded at least 7.5 magnitudes; this behavior is characteristic of a fast nova.

Hitherto, Nova Herculis has been unique in showing an emission spectrum before maximum. The appearance of the same features on the discovery spectrum plate of Nova Tucanae, though this was made two days after maximum, leads

Mr. Smith to suggest that this may be a second case, one in which the emission persisted somewhat longer than it did for Nova Herculis.

Variable Stars in M3

Where do RR Lyrae (cluster-type) variables fall in the diagram formed by plotting color index against apparent magnitude for the individual stars in a globular cluster? Drs. Morton Roberts and Allan Sandage have studied this problem for the globular cluster M3, in Canes Venatici, using 50 plates taken in blue and yellow light with the 100-inch reflector at Mount Wilson Observatory.

All of the RR Lyrae variables were found to lie in a sharply delineated region of the color-magnitude diagram, unoccupied by nonvariable stars, extending from color index 0.00 to +0.23 and centered on photovisual magnitude 15.68. There were three stars previously thought to be nonvariable that fell within this region; they are now shown to be variables with small amplitudes.

The amplitude of light variation is small for RR Lyrae variables just within the region, but it rises to a maximum of 1.6 magnitudes, in blue light, for a color index +0.07. Unlike the period-luminosity relation for ordinary Cepheid variables, the RR Lyrae stars of shorter periods are brighter than those of longer periods.

In a comment on this paper, Dr. M. Schwarzschild, Princeton University Observatory, said the work appears to confirm the belief that if a star *can* pulsate it does so. Nevertheless, we still do not know the cause of the pulsation of stars.

AMERICAN ASTRONOMICAL SOCIETY MEETING

The 91st meeting of the American Astronomical Society will be held at the University of Michigan, Ann Arbor, June 20-23. There will be a symposium on "Turbulence and Magnetic Fields in the Photosphere," and a special paper by Dr. A. B. Meinel, on the aurora and the airglow. The Yerkes Observatory astronomer is to be awarded the Helen B. Warner prize for astronomy.

The Association for Computing Machinery is meeting in Ann Arbor later the same week, and tentative plans call for the astronomers and the computers to meet in one or two joint sessions on subjects of mutual interest. On Monday evening, June 21st, there will be a trip to the Portage Lake Observatory, and on Thursday morning a trip to Lake Angelus for inspection of the McMath-Hulbert Observatory. These stations of the Observatories of the University of Michigan are about 15 and 50 miles from Ann Arbor, respectively.

NEWS NOTES

By Dorrit Hoffleit

UNGAVA CRATER ORIGIN

The crater in northern Canada known hitherto as Chubb crater has been officially named Ungava Crater, from its location in the Ungava region of Quebec, by the Canadian Board of Geographical Names. J. M. Harrison, of the Geological Survey of Canada, spent six days there in the summer of 1953; in the *Journal* of the Royal Astronomical Society of Canada he reports that the crater is of preglacial origin and that it appears to have resulted from the impact or explosion of a meteorite.

He points out that the glacial action has largely obliterated the superficial characteristics considered by some as necessary to prove the meteoritic origin of such a terrestrial crater, and that other origins are inconsistent with the observed geological features of the terrain. No glacial debris has been found within the crater itself, which Dr. Harrison believes partially deflected the flow of glacial ice because its walls protruded more than 300 feet above the surrounding area. Furthermore, water frozen within the crater before glaciation began may have provided a smooth surface for glacial ice to slide over. There are boulders perched on the rim of the crater, very delicately balanced in many cases, as is characteristic of many boulders in glaciated regions.

ELEMENT 100

University of California scientists have produced an element of atomic number 100, by "fattening" plutonium atoms with neutrons, in two stages. Element 100 has a half-life of about three hours, decaying by the emission of alpha particles. Chemically, it acts like no other element known, and has the properties predicted for it by means of a concept developed by Dr. Glenn T. Seaborg. This work was done under his leadership at the AEC Materials Testing Reactor at Arco, Idaho.

The process involved adding neutrons to plutonium until some californium (element 98) was formed; the sample was removed from the reactor and the californium separated out by chemical means. These atoms, of atomic weight 252, were returned to the reactor and bombarded with more neutrons, producing first element 99, of atomic weight 253, and then element 100, of atomic weight 254.

Element 99, having a half-life of about a month, had not previously been reported as having been produced earlier at the Arco reactor, where it was first made in December of last year.

ERNEST ESCLANGON

Ernest Esclangon, director of the Paris and Meudon Observatories from 1929 until his retirement in 1946, and president of the International Astronomical Union at its 1938 Stockholm meeting, died on January 28th at the age of 77. The dean of French astronomers, Prof. Esclangon's work included celestial mechanics, time, solar eclipses, ballistics, and atmospheric acoustics.

During World War I, he developed for the military a widely used system for sound location of enemy artillery. In 1918 he was made co-ordinator of antisubmarine research. At the close of the war he became director of the Strasbourg Observatory, a position he held until he succeeded H. Deslandres at Paris.

Shortly before his death, Prof. Esclangon was working on the problem of establishing artificial satellites of the earth.

BERKELEY CONFERENCE

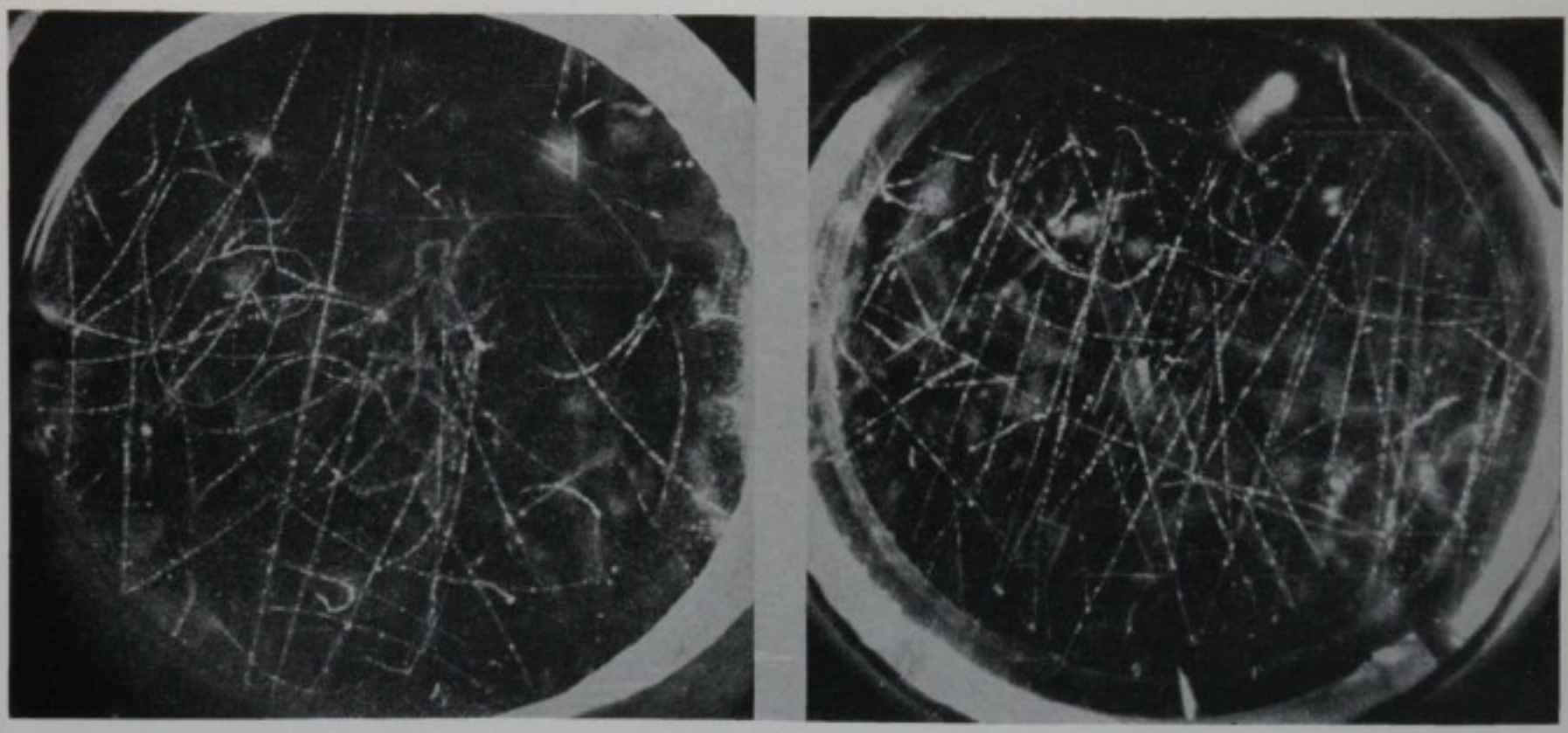
The astronomy department of the University of California at Berkeley is arranging an astronomy conference between August 16th and September 15th, for college and university instructors and other qualified persons, with the support of the National Science Foundation. The principal lecturer will be Dr. Bart J. Bok, Harvard College Observatory, who will discuss the structure of the galaxy. Dr. A. J. Deutsch, Mount Wilson and Palomar Observatories, will talk on astrophysics. Applications should be addressed to the Department of Astronomy, University of California, Berkeley 4, Calif., before June 15th. Membership will be limited to about 20.

IN THE CURRENT JOURNALS

MAGNETIC STORMS, AURORAE, IONOSPHERE AND ZODIACAL LIGHT, by Edward O. Hulburt, **Scientific Monthly,** February, 1954. ". . . there are two effects which at all times have confused thinking about the outer fringe of the earth's atmosphere . . . the sweep-up by the earth of interplanetary material and the electric charge brought to the earth by cosmic rays."

A FAMILY OF SOLAR ECLIPSES, by Richard M. Sutton, **Scientific American,** February, 1954. "The family to which the eclipse of next June 30 belongs is one of 40 now periodically visiting the earth. We can follow this family from its birth nearly 900 years ago to its death four centuries hence."

FACING PICTURE: Planets are difficult subjects for photography, and Saturn is no exception. This famous Barnard photograph with the Mount Wilson 60-inch shows the crape ring in front of Saturn's disk and several of the belts and zones that may be seen with moderate-sized telescopes at the current opposition of the planet, as discussed by D. P. Avigliano on page 240.



An extensive cosmic ray shower was recorded at the University of Manchester, England, where these two cloud chambers (each 28 centimeters in diameter) were operated simultaneously at the extremities of a circle 20 feet in diameter. From the tracks in the chambers, it is inferred that over 60,000 particles passed through the circle, and that the total energy of the shower was at least 1,000 billion electron volts. A 1,000-gauss magnetic field applied to the left chamber caused curvatures of the tracks of charged particles, to permit their identification. Photograph by A. C. B. Lovell and J. G. Wilson, from "Cloud Chamber Photographs of the Cosmic Radiation," by Rochester and Wilson, Pergamon Press, Ltd.

The Story of Cosmic Rays--IV

By W. F. G. Swann, *Director*
Bartol Research Foundation, Franklin Institute

4. Cosmic Rays in the Atmosphere

The Primary Cosmic Radiation. As stated earlier, primary cosmic rays appear to contain samples of every kind of non-radioactive atom in the universe. The chief constituent is the proton, the nucleus of the hydrogen atom. The percentages of the elements vary according to different observers, but from representative data they are in the ratio of 4,000 particles of hydrogen to 1,000 of helium, to 35 of carbon, nitrogen, and oxygen, to 10 of all nuclei with atomic numbers greater than 10.

There can be no mesotrons in the primary radiation, for the mean life of the mu-mesotron, the longest-lived of the mesotron family, is only 2.3 microseconds when the particle is at rest, and even with energies as great as 100 billion electron volts, the mean life is only 2/1,000 of a second. There is no place from which the mesotrons could have come, for the nearest body that could reasonably be a candidate for supplying them is the sun, and a particle traveling with the velocity of light itself would take more than eight minutes to reach us from the sun.

Lifetime considerations rule out even neutrons as possible components of the primary radiation, since neutrons have a mean life of the order of 18.5 minutes. The sun is the only body from which they could reach us, and if they came from the sun in appreciable amount, there would be a much larger change in cosmic ray intensity from day to night than experiment reveals. Unlike charged particles, whose paths can be bent by the earth's magnetic field, neutrons could not reach the side of the earth opposite their point of origin.

The Production of Mesotrons. When the protons of the primary radiation enter our atmosphere, they very rapidly disintegrate into mesotrons, as the result of collisions with the nuclei of atoms. The protons disappear so rapidly by this process that only about a third of them remain at an altitude where the pressure is 1/10 of an atmosphere.

Even in the case of the heavier atoms contained in cosmic rays, it is the protons in their nuclei that are responsible for giving birth to mesotrons; and since mesotrons are the most important constituent of the rays that we observe at lower altitudes, a helium atom, containing two protons, is twice as effective in producing mesotrons as is a single proton. An atom like iron, with 26 protons in its nucleus, is 26 times as effective as is the proton itself. If iron atoms, for example, were only one per cent as numerous as free protons, they would nevertheless contribute about one third as many mesotrons as do the free protons. Thus, despite the relatively small percentage of atoms of high atomic weight, it turns out that 50 per cent of the mesotrons produced in the atmosphere come from primaries which are heavier than protons.

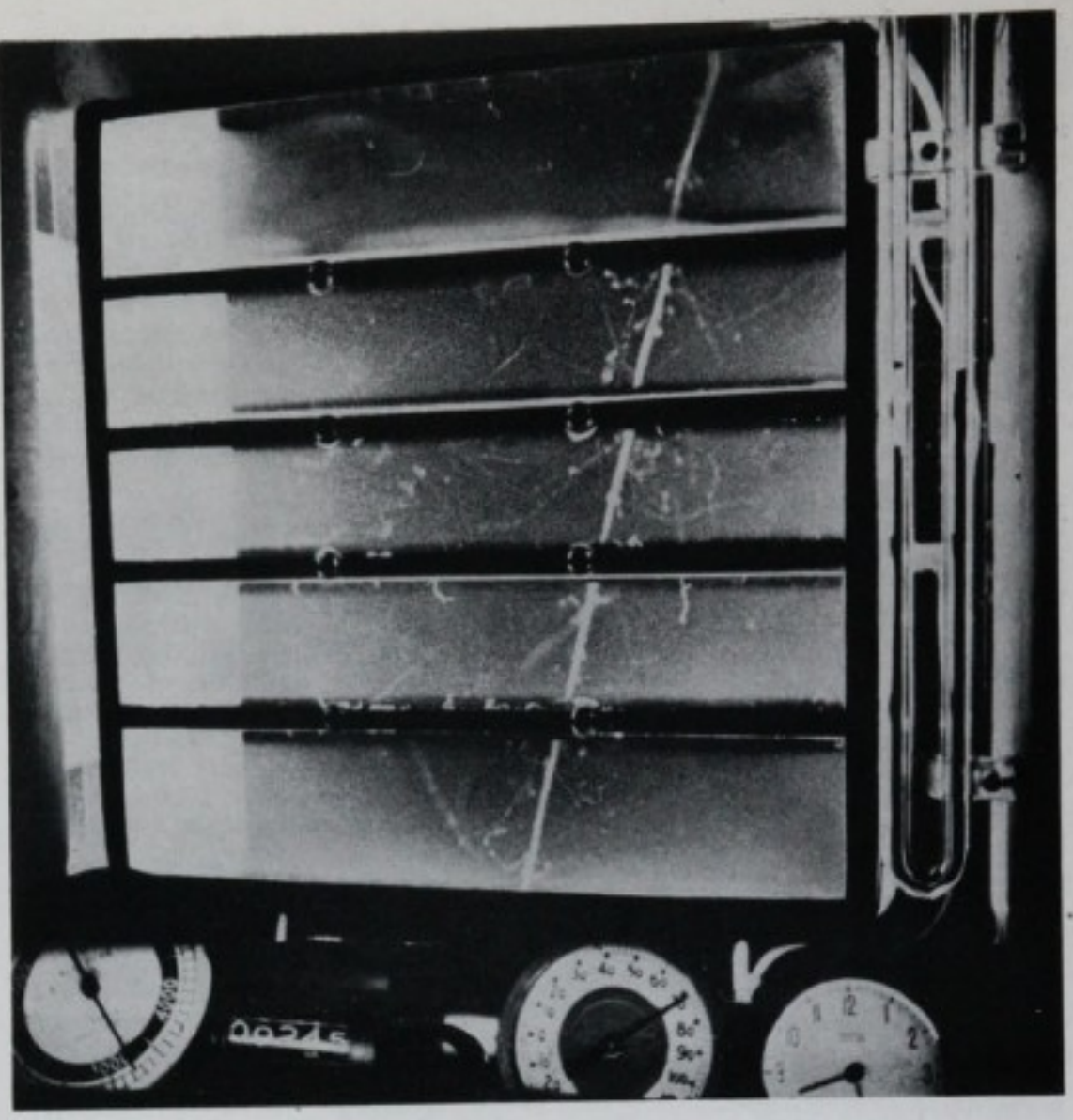
When a proton, either free or in combination in a nucleus, enters the atmosphere and collides with the nucleus of an atom of air, it is probable that, in the first instance, pi-mesotrons are produced, as shown in the genealogical chart in our March installment. A slowly moving pi-mesotron with a mean life of 10^{-8} second would travel only a meter or so before disintegrating to form a mu-mesotron. A slow mu-mesotron, with a mean life of the order of 2.3 microseconds, would go less than 700 meters before disintegrating into an electron.

Mesotrons of higher energy live longer and penetrate farther, so that a mesotron of 10 billion electron volts would live for about 2/10,000 of a second and in that time could travel 60 kilometers. Thus, from mean-life considerations alone it would have no difficulty in penetrating the whole atmosphere. As a matter of fact, only about 1.3 billion volts of its energy is necessary to allow for all the ionization it would cause on such a journey, so that neither ionization

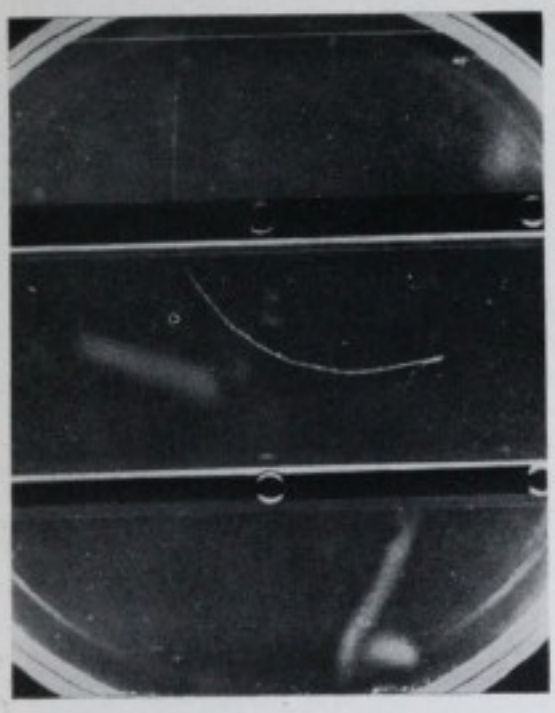
loss of energy nor mean-life considerations would prevent such a mesotron from reaching the earth's surface. Indeed, some of the mesotrons are produced with such high energies that they can penetrate far more than the thickness of the earth's atmosphere, and cosmic ray intensity has a measurable value at depths below the earth's surface comparable with 250 meters of water.

Starting in the outer regions of the atmosphere, we have only the primaries. These decrease rapidly with descent, by the production of mesotrons, so that the mesotron intensity rises as we descend into the atmosphere until, at a depth of about 1/10 of the whole atmosphere, the rate of production of mesotrons balances the rate of decay and there is a maximum in the mesotron intensity. Below this point, the disappearance of mesotrons (as a result of mean-life considerations enhanced by energy loss) excceds the rate of formation, and the mesotron intensity declines and continues to decline with further descent. The high-energy mesotrons penetrate far, while the low-energy mesotrons, either by decay or by coming to rest as a result of energy loss, travel only shorter distances.

The Production of Electrons. How does the number of electrons change with height? Near the extreme upper limits of the atmosphere cosmic ray electrons are very few, because the mesotrons that breed them have not yet been produced by the primaries in sufficient number. The mu-mesotrons that are produced with low energy in the first tenth of the atmosphere die very near the places where they are born, giving rise to electrons. Higher-energy mesotrons, which can travel farther, do not die as rapidly and therefore do not produce electrons as copiously as do the low-energy mesotrons. Therefore, many more electrons will be formed in the higher regions of the atmosphere than in the lower.



This cloud chamber, carried aloft to 95,000 feet, recorded the passage of a primary cosmic ray particle, a heavy nucleus of atomic number about 10, which passed through a carbon plate and three lead plates without significant change, producing a number of electrons. The mercury manometer, right, indicates the outside barometric pressure and hence the altitude. Photograph by E. P. Ney, F. Oppenheimer, and P. Freier, University of Minnesota.



Coming to rest in a field of 7,250 gauss, in a chamber filled with argon gas, this negative mesotron decays to form an electron of 13 million volts energy, which makes the short weak track leftward and down from the point of formation. Note the increased ionization by the mesotron as its energy wanes. Photograph by R. B. Leighton, C. D. Anderson, and A. J. Seriff, California Institute of Technology, courtesy the "Physical Review."

Each electron which is produced, however, goes through the process of pair production (discussed in the March issue) and gives rise to progeny which increase in numbers as we descend from the point where the original parents were formed. The increase continues until it becomes balanced by the loss of electrons, when the ionization which they produce reduces their energy below the point at which the electrons can reproduce themselves. Thus, each electron formed has its own little genealogical history involving rise in progeny to a maximum with descent, followed by a decline in numbers with further descent. A combination of the life histories of all the parent electrons produced near the top of the atmosphere thus results in a rise of the electron intensity as we descend, a maximum being reached at a depth corresponding to about 1/10 of the atmosphere, after which the electron intensity diminishes rapidly with further descent.

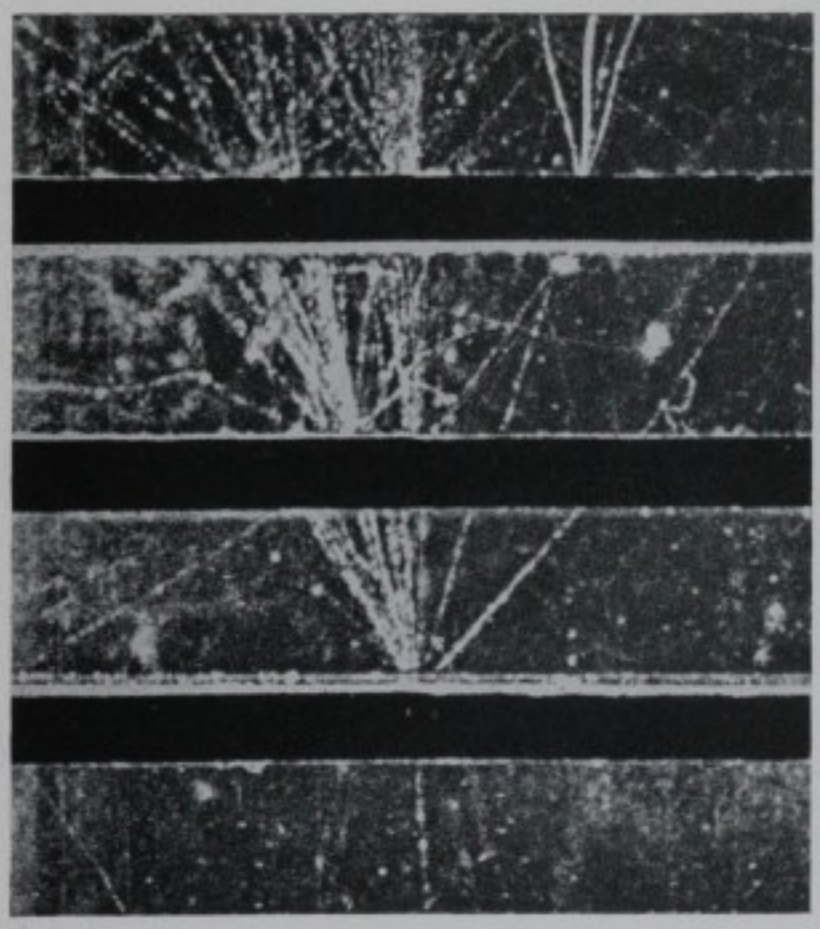
The situation is such that practically none of the parent electrons produced in the higher regions of the atmosphere can succeed in having any progeny at the earth's surface. In fact, a parent electron would have to have an energy of some 10 trillion electron volts in the outer regions of the atmosphere to have a single offspring at the earth's surface!

Such electrons as we find in the lower atmosphere come partly from the relatively rare deaths of fast-moving mesotrons and from the deaths of mesotrons which have been slowed down by ionization energy losses. Another source of electrons is closely related to ionization itself: If a mesotron passes sufficiently near an electron in an atom, it may hurl that electron out with an energy very high compared with the normal energy given to electrons by mesotrons in ordinary ionization. Electrans shot out of atoms with high energy in this manner are referred to as *knock-on electrons*, and they contribute appreciably to the elec-

tron component of the radiation measured, particularly at low altitudes.

Neutrons. It is of importance to observe that disintegration of the proton in the primary charged atom leaves free neutrons, which should therefore be fairly plentiful in the places where proton disintegration occurs. Experiment, indeed, reveals the fact that neutrons do exist in the atmosphere, and their intensity mounts very rapidly as high altitudes are approached. It is not at present known whether the neutrons in high-energy atoms disintegrate on collision as protons do, but even if such is the case, we may expect to find some neutrons that have escaped destruction of this kind by becoming reduced in energy in the collision process to the point at which they no longer invite destruction.

Extensive Showers. The phenomena above are the main contributions to what we measure as the cosmic radiation. However, there are other comparatively rare but very interesting phenomena. In extensive showers, some of the rays observed at sea level arrive so close together in time, in spite of wide separation in their places of arrival, as to suggest that they have a common origin, probably in one very high-energy primary particle. P. Auger, who has studied these matters intensively, states that such showers of rays may correspond to more than a million particles arriving simultaneously over an area of 25 acres. If we should imagine these particles to originate through pair production from a single high-energy electron, it would be necessary to assume for that electron an energy between 10^{15} and 10^{16} electron volts. Taking all losses into consideration, as high as 10^{17} electron volts for the parent particle has been estimated as necessary to account for some of the phenomena observed.



A high-energy particle, probably a proton, while passing through a lead plate undergoes an interaction that produces cascades of electrons and photons, and penetrating particles. The two cascades below the second plate have energies of the order of two billion electron volts. The track going to the left is probably a proton of 100 million volts; to its right is a proton or a pi-mesotron that undergoes the nuclear encounter producing at least four particles at the lower left. This photograph by C. Y. Chao is from "Cloud Chamber Photographs of the Cosmic Radiation," by Rochester and Wilson, courtesy the "Physical Review."

Nuclear Disintegration Caused by Cosmic Rays. Another matter of great interest in nuclear physics, although possibly of subsidiary interest to cosmic ray students, is nuclear disintegration produced by the rays. The neutrons in the upper atmosphere doubtless play a significant role in promoting such nuclear disintegrations.

It has been customary to classify the events observed according to the number of prongs which emanate from the centers of collision of the rays with the nuclei of the atmospheric atoms. As stated in April, analysis of the nature of these tracks, their angular spread, their ranges in matter, combined with the fundamental principles of the conservation of energy and momentum during collision, serve to enhance our knowledge in that most mysterious realm of nuclear theory which involves the nature of nuclear forces.

(To be continued)

AIR FORCE AND OTHER EXPEDITION PLANS

(Continued from page 215)

horizontal sweeps along the horizon in an attempt to distinguish between the zodiacal light and the dawn.

Prof. Arpad Elo will lead a joint expedition of Marquette University and the Milwaukee Astronomical Society to the Keweenaw peninsula in Upper Michigan. Using equipment similar to that of the Air Force expeditions, this party will take motion pictures of the flash spectrum, in order to time the second and third contacts by Lindblad's method. The records will be analyzed at Ohio State University.

The equipment consists of a single-mirror coelostat which reflects sunlight into a 6-inch reflecting telescope. At the opening of the telescope tube is placed a 4-inch, 14° objective prism to provide the spectrum of the solar atmosphere. Light leaving the telescope by a conventional diagonal enters a 35-mm. motion picture camera, in which the film is motor-driven at constant speed. Exposures will be made at accurately known times at 24 frames per second. A second film will record WWV time signals, pulses from a secondary timekeeper, and pulses indicating when the spectrum exposures are made.

The Milwaukee Astronomical Society is sending a second party, consisting of six persons, to Canada. This group will observe from Mattice, Ont., unless it can arrange transportation to Rupert House at the southern tip of James Bay. The latter site would require traveling by boat from Moose Factory nearly a hundred miles across James Bay. Whether this can be done is uncertain, as the ice may not be out in time.

The S.S. *South American*, of the Georgian Bay Line, on its regularly scheduled cruise of the Great Lakes from Buffalo to Duluth and return, leaves the latter city on Tuesday evening, June 29th, at 8:30 CST, and arrives at Houghton, Mich., on the Keweenaw peninsula, at 10:00 EST the morning of the eclipse. Paul W. Stevens, 2322 Westfall Rd., Rochester 18, N.Y., has ascertained that the ship will be on Lake Superior and well inside the path of totality at the time of the total phase. He suggests other interested persons join him in cruising the Great Lakes from some easterly point, such as Buffalo or Detroit, and is preparing to observe the eclipse from shipboard. He invites correspondence from persons desiring additional information.

Eclipse observers who plan to travel to Canada will find that Mattice and Kapuskasing, Ontario, are among the most accessible places within the path of totality. Information on travel by railroad to these points can be obtained from C. H. Ladue, General Agent, Canadian National Railways, 497 Boylston St., Boston 16, Mass.

Shadow bands will be studied by an eclipse expedition to Sweden of the California Academy of Sciences. The three-man party, which includes Preston Butler and Leon Salanave, will make photoelectric and photographic records of the bands, together with simultaneous weather and seeing observations, in order to get quantitative data on this elusive phenomenon.

Red Shifts of Spectral Lines

By Otto Struve, *Leuschner Observatory*
University of California

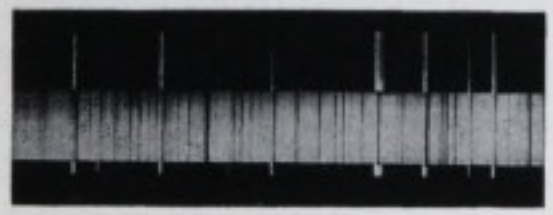
AMONG the problems of astrophysics, one of the most intriguing is the tendency of many astronomical objects to show a preponderance of red shifts in their spectral lines, as if they were all receding from the earth. That is, such recession would be implied were there no explanations for the red shifts other than the principle first proposed by Doppler in 1842 that red shifts in a spectrum are caused by relative motion of the light source away from the observer.

Last year marked the 100th anniversary of the death of Christian Johann Doppler, which occurred on March 17, 1853, and we may here call attention to his contribution to spectroscopy by considering modern interpretations of red shifts in a variety of objects: sun, stars, and galaxies.

According to Doppler's principle, as later clarified by Fizeau, when a star is at rest with respect to the earth the stellar and laboratory lines of a particular element coincide; there is no shift. When the star approaches, however, the stellar lines are shifted toward the violet side of the spectrum by an amount which, in angstrom units, equals the ratio of the velocity of the star and the velocity of light, multiplied by the undisturbed wave length of the line. When the star recedes, the shift is in the same proportion toward the red side.

Among thousands of stars whose spectra have been accurately measured, some show red shifts, while others have violet shifts. But on the average the red shifts are slightly more numerous, as though our galaxy were slowly expanding. This fact, discovered by E. B. Frost and J. C. Kapteyn at Yerkes Observatory, is known as the K-effect. It is most prominent among the *B*-type stars.

But few astronomers now believe that our galaxy is really expanding. The statistical interpretation of the radial motions of the *B* stars is complicated by the phenomenon of galactic rotation, and it is probable that the K-effect represents, in part, the relative velocities of the *B* stars and the sun in their orbits around the galactic center.



The Doppler effect in a star's spectrum is shown here. The relative motion of star and earth causes the dark iron lines in the stellar spectrum to shift with reference to the laboratory spectrum of the same element (bright lines).

Even more perplexing are the radial velocities of the very hot *O*-type stars which are often located in galactic star clusters. R. J. Trumpler found in 1935, at Lick Observatory, that these stars have *apparent* velocities of recession that exceed those of the other stars in the same cluster by 10 or even 15 kilometers per second. According to Doppler we would infer that in their outward motions the *O* stars pass through the clusters. But this is not logical, and we must attribute the Trumpler effect to some other cause.

A possible clue to this cause was provided by W. S. Adams, at Mount Wilson Observatory, who found that the companion of Sirius also seems to run away from its luminous primary, instead of revolving around it in the elliptical orbit that direct visual observations show conclusively to be the actual case. The red shift of the spectral lines of the companion of Sirius cannot be a Doppler effect of recession.

The explanation of the red shifts of lines in white dwarf stars—of which Sirius B is the most famous representative—had been predicted by A. Einstein in his theory of general relativity. A popular account by Philipp Frank, of Harvard University, was printed in *Sky and Telescope* in 1942 (and is still available in pamphlet form). Readers are advised to consult Dr. Frank's enlightening discussion before they attempt to study more technical books on relativity.

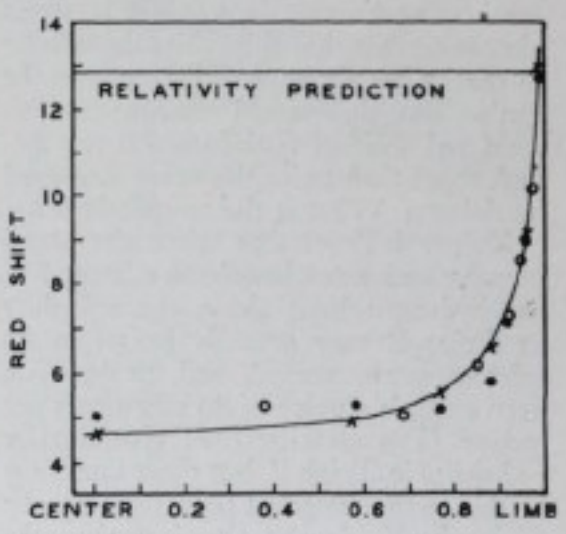
We have already seen that the Doppler effect arises when the star and the earth are moving uniformly with respect to one another. Instead of receiving n impulses per second from the star, the observer receives $n' = n\ (1 + v/c)$ impulses, where v is the relative velocity and c is the velocity of light. Since n, the frequency, is equal to the velocity divided by the wave length, λ, we find Doppler's formula to be

$$\frac{\lambda - \lambda'}{\lambda'} = \frac{v}{c}.$$

This is the primary Doppler effect, for uniform relative motion of the source and the observer.

But if the motion is accelerated, there is added a secondary Doppler effect, which in ordinary nonrelativity physics is always very small and cannot be measured. In 1912, Einstein advanced the "principle of equivalence," according to which the effect of gravity upon a ray of light must be the same as the effect of an acceleration. Hence, a quantum of light speeding from the sun's photosphere toward the earth expends energy in freeing itself from the gravitational field of the sun. The effect is proportional to the mass of the sun (2×10^{33} grams) and inversely proportional to its radius (7×10^{10} centimeters). As a result, lines in the solar spectrum should be shifted to the red by an amount equivalent to a recession of 0.6 kilometer per second.

Measurements by C. E. St. John, at Mount Wilson, of 1,537 lines in the solar spectrum have on the average indicated the expected shift, but there were complicating factors that were also investigated by J. Evershed and by Adams.* The most important of these consists of a progressive increase in the amount of the red shift, between the center and limb of the sun's disk. Our accompanying diagram shows the change of the red shift according to a group of Potsdam observers under E. Finlay-Freundlich, now of St. Andrews University, Scotland, and according to Miss M. G. Adam, of Oxford. The Einstein effect, on the other hand, predicts a constant value of the red shift over the entire disk.



Red shifts in the spectrum of the sun are here plotted for different points between its center and its edge. The ordinate unit is 0.001 angstrom. The dots are Oxford observations; open circles are Potsdam values. The crosses and continuous curve represent Finlay-Freundlich's theory. All these values lie well below the prediction of relativity, except at the limb.

For the companion of Sirius, we found in our December, 1953, discussion of white dwarfs that its mass is about equal to that of the sun while it has only 1/50 the radius of our star. Hence, the expected Einstein shift would be $0.6 \times 1 \times 50$, or 30 kilometers per second. This is of the same order of magnitude as the velocity of recession, 20 kilometers per

*For a comprehensive discussion, see Charlotte E. Moore's article, page 186 of *The Sun*, Vol. I, edited by G. P. Kuiper, University of Chicago Press, 1953.

second, measured by Adams and later confirmed by J. H. Moore at the Lick Observatory.

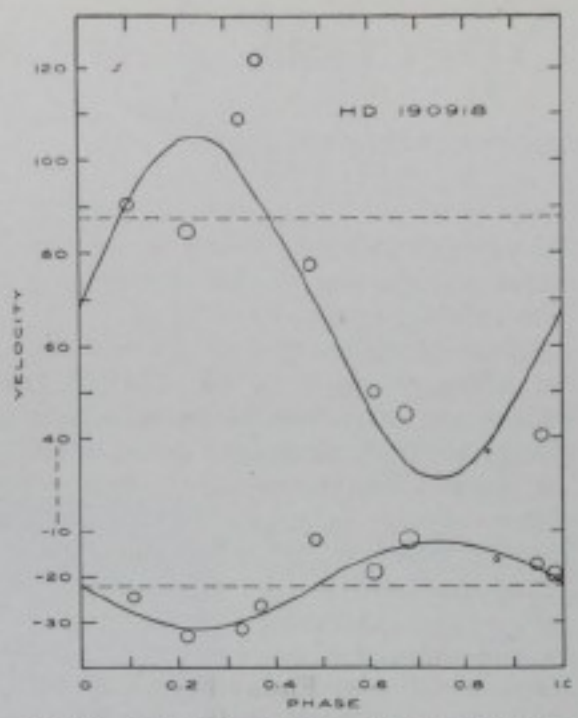
However, our estimate of the radius of Sirius B was based upon the rather uncertain assumption that its surface temperature is similar to that of Sirius A. Hence, in the past, astronomers have usually reversed the Einstein formula, and derived the radius of Sirius B from the red shift as measured by Adams and Moore.

But there is a serious discrepancy between this value of the radius and that computed from the theory of degenerate matter discussed in January. Then we found that the radius of a white dwarf that consists of helium is much smaller than of one that might consist of hydrogen. According to G. P. Kuiper, the assumed radius of Sirius B, 1/50 the solar radius, would require it to consist of pure hydrogen. Since physical considerations make this impossible, it seems almost certain that this white dwarf star in reality has a radius of only 1/100 the sun's. But this would require an Einstein red shift of 60 kilometers per second, more than twice the value measured by Adams. What is the trouble here?

Kuiper believes that when the measurements of wave lengths are limited to the hydrogen lines alone, the red shift in Sirius B may actually be 50 to 60 kilometers per second, and he does not even exclude a value of 80 kilometers per second. The metallic lines give smaller red shifts in Sirius B, but these lines may be due to the scattered light from nearby Sirius itself, despite the fact that the original investigators had attempted to correct their results for such atmospheric scattering.†

An entirely different explanation of the red shifts in stars and galaxies has recently been advanced by Finlay-Freundlich, who last year reviewed before the academy of sciences in Goettingen the entire available information concerning red shifts of spectral lines in different types of stars. He does agree with the prediction of a small relativity red shift, which should affect all areas of the sun and all lines in its spectrum equally.

He adds, however, a proposal that the photons of light in the atmosphere of the sun might interact with one another and undergo a change in wave length, or frequency, due to a loss of energy during their mutual interactions. Since there is as yet no physical interpretation of such a "fatigue effect," the best that can be done is to make the simplest possible assumption, namely, that the ratio of the red shift to the wave length is proportional to the energy density of the radiation and to the length of the path, L, of the light.



Radial velocity curves of the binary star HD 190918, by O. C. Wilson, of Mount Wilson Observatory. The dashed lines indicate the mean value of the radial velocity for each star, the Wolf-Rayet component being at the top. From the "Astrophysical Journal."

According to Planck's law, the energy density is proportional to the fourth power of the temperature, T. Hence, we can write

$$d\lambda/\lambda = AT^4L,$$

where A is an unknown constant which may be determined from the observed red shifts in the sun and in different types of stars.

If we assume for the moment that in the atmosphere of the sun and other stars of the main sequence the path length is about 10^7 centimeters, we may derive A with the help of the B-type stars in the Orion nebula. Relative to the nebula itself, these stars seem to be receding at about 11 kilometers per second. Finlay-Freundlich believes that the true relativity red shift of the B-type stars amounts to about one kilometer per second. This leaves for the fatigue effect a fictitious motion of +10 kilometers per second, giving a value of $d\lambda/\lambda$ of 10/300,000, or 3.3×10^{-5}. For the temperature of an average early B star, we take 20,000°. Hence, the constant A turns out to be 2×10^{-29}.

Now apply this value of A to the sun, using for its temperature 6,000°. The red shift would be reduced, compared to that in B stars, by a factor of $(6{,}000/20{,}000)^4$, which is about 1/100. Thus, at the center of the sun's disk the fatigue effect would correspond only to approximately 1/10 kilometer per second, the remainder being accounted for by the Einstein shift. Finlay-Freundlich then fits his theory to the observed increase in red shift toward the sun's edges by the effect of the increased path length through the solar atmosphere for light coming to us from points near the limb. If the observed increase (plotted in the graph on page 225) is to be explained in this way, the relativity effect can be permitted to have only one fifth the value predicted by Einstein; thus, at the center of the sun's disk its value would be about equal to that of the fatigue effect, but at the limb the fatigue effect would predominate.

Similarly, for the O stars of Trumpler the red shifts would now be accounted for by the fatigue effect, leaving little or no relativity shifts.

Finlay-Freundlich has also applied his theory to the spectroscopic binary HD 190918, for which the observed velocity curves are shown in the accompanying graph. The B-type component has the lower curve, with a mean velocity of approach of 22 kilometers per second. Normally, the other component of a binary system would have to have a range of velocities averaging this same value, representing the actual motion of the center of gravity of the two stars. But the Wolf-Rayet-type star that forms the other component of HD 190918 has a velocity curve appearing to average 88 kilometers per second motion away from us! Obviously, the *mean* velocity found in this way cannot represent actual motion of the Wolf-Rayet star, and we must look for another explanation.

Therefore, the relative red shift of the Wolf-Rayet star is attributed to its very high temperature, 40,000°, compared to the 20,000° temperature of the B star. If we again assume for the latter star a fatigue shift corresponding to 10 kilometers per second, the expected fatigue shift of the Wolf-Rayet star would be increased by a factor of $(40{,}000/20{,}000)^4$, or 16 times, to a value of 160 kilometers per second. This roughly calculated discrepancy of 150 is of the same order of magnitude as the observed difference of 110 kilometers per second.

Finally, Finlay-Freundlich attempts to apply his theory to the red shifts of the galaxies that are the observational basis for belief in an expanding universe. According to Hubble and Humason, the apparent velocity of expansion increases by 500 kilometers per second for every 1,000,000 parsecs (3×10^{24} centimeters) increase in distance from us. Assuming fatigue to take place uniformly in intergalactic space, and adopting the value of A found from the B stars, Finlay-Freundlich could solve his equation for T, the temperature of intergalactic space; his result is two degrees above absolute zero.

These computations were made before the new distance scale of the galaxies was announced by Baade in 1952. With the new scale the temperature of intergalactic space would be somewhat less than 2° absolute.

Finlay-Freundlich's discussion is intriguingly ingenious. It has the advan-

†This and other possible explanations are listed in the latest edition of *Theory of Atomic Nucleus and Nuclear Energy Sources*," by G. Gamow and C. L. Critchfield, Oxford University Press, 1949, page 293.

tage of explaining in a single theory a number of detached facts. But it also raises some very serious doubts:

1. The theory is based upon the *B* stars in the Orion nebula. But other *B* stars do not show a large K-effect; and what K-effect there is can be accounted for by the dynamical properties of the galaxy. Of the utmost importance in this connection is R. M. Petrie's recent conclusion that those *B* stars which are members of visual binaries or of galactic clusters "do not give any support to the hypothesis that the *B* stars generally will yield a positive K-term, from the red shift, of one or two km/sec." There is not even the expected gravitational red shift of this order of magnitude.

2. The disparity of the mean velocities in spectroscopic binaries having one Wolf-Rayet and one *B*- or *O*-type component is sometimes not at all consistent with the picture advocated by Finlay-Freundlich. Thus, W. A. Hiltner has found entirely different red shifts from the individual emission lines of Wolf-Rayet components. There also appear to be cases where the mean velocities differ, although the temperatures of the components, and presumably also their path lengths, are the same.

3. It is disturbing that in the sun the relativity red shift does not appear to exist—if Finlay-Freundlich's theory is accepted. Most astrophysicists believe that the general theory of relativity is so fully confirmed by other evidence, astronomical as well as physical, that the relativistic velocity of +0.6 kilometers per second *must* exist in the sun's light. If it does not appear in the observations, then perhaps the best explanation is still St. John's: that systematic motions in the solar atmosphere conceal the relativity effect.

4. As we have seen, the white dwarfs do not fit the fatigue theory. For them T is about 10,000°, but the path length is certainly much shorter than 10^7 centimeters. Hence, Finlay-Freundlich suggests that their red shifts may be analogous to the "decapitated" relativity red shift of the sun. If the latter has only one fifth the value predicted by Einstein, then the white dwarfs might also show only a fraction of the Einstein effect. This would account for the measured shift of 20 kilometers per second, as opposed to the approximately 80 predicted for a white dwarf consisting of helium. But surely this one fifth, or one fourth, of the expected red shift can make no serious claim to represent the theory of relativity!

5. Systematic motions in the form of large turbulent eddies are known to exist in some stellar atmospheres. And systematic motions of infall are one of the most conspicuous features of solar prominences. Thus, red shifts may sometimes be due to *real* primary Doppler effects.

6. There is at present no indication from physical theory that a fatigue effect exists. Nor are there any laboratory observations that would lead us to expect one. The astronomical path lengths, of the order of 10^7 centimeters are, of course, not realized in a laboratory. But the astronomical temperatures are not excessive, and the precision of the measurement of wave lengths is greater in the laboratory. Even though it would be difficult to measure the effect *macroscopically*, as is done in astrophysics, there should be *microscopic* effects when two photons interact directly. Thus far, no such interaction has been discovered.

Amateur Astronomers

Program of the Convention at Madison

A TENTATIVE program has been announced for the general convention of the Astronomical League at Madison, Wis., July 2-5, with convention headquarters at Babcock Hall, University of Wisconsin. The opening session will begin at 1:30 on Friday afternoon, July 2nd, with a roll call of societies, reports of officers and section chairmen, and other business. At 6:30 that evening there will be a trip to Yerkes Observatory at Lake Geneva.

A meeting of the North Central region will be held at 9:00 a.m. Saturday, followed by a session for papers on solar observing. After an early afternoon business session, planetary observing will be discussed, and the convention banquet will be held at 7 o'clock.

Sunday morning the exhibits will be open for inspection. In the afternoon there will be an observing session for lunar enthusiasts, followed by a program on junior activities. Eclipse experiences will be reported Sunday evening.

After a program concerning instruments Monday morning, the final business meeting will convene at 11:30 a.m.

The University of Wisconsin Planetarium, the Washburn Observatory, and the Madison Astronomical Society Observatory will be open for inspection during the convention, conditions permitting.

Persons wishing to present papers at the convention should write the chairman of the program committee, Ross H. Bardell, 600 W. Kilbourn Ave., Milwaukee 3, Wis. Titles are required not later than June 1st, and a copy of each paper must be in the committee's hands before the convention opens.

See page 161 of the March issue for information on registration, exhibiting, and the eclipse bus tour.

AAVSO MEETING

The spring meeting of the American Association of Variable Star Observers will be held at Columbia University, New York City, in conjunction with the university's bicentennial celebration. On Friday, May 7th, the association's council will meet, and on Saturday there will be sessions for business and papers.

NORTHEAST CONVENTION

The Northeast region of the Astronomical League will hold its convention on the weekend of May 15-16 in Worcester, Mass. The Aldrich Astronomy Club is the host society.

Registration will begin Friday evening, at the Museum of Natural History, Cedar Street, and a star party will be held at the society's observatory, weather permitting. On Saturday there will be morning and afternoon sessions for papers, including an hour for junior astronomers. Those wishing to present talks on any subject of astronomy should communicate immediately with the program chairman, Charles A. Federer, Jr., Harvard College Observatory, Cambridge 38, Mass.

The convention chairman is Dr. Leon A. Storz, 9 Gaskill Rd., Worcester.

THIS MONTH'S MEETINGS

Buffalo, N. Y.: Buffalo Astronomical Association, 7:30 p.m., Museum of Science. May 5, round table, "Making a Telescope."

Chicago, Ill.: Burnham Astronomical Society, 3:30 p.m., Adler Planetarium. May 9, John Sternig, Glencoe Public Schools, "The Planet Mars."

Cleveland, Ohio: Cleveland Astronomical Society, 8 p.m., Warner and Swasey Observatory. May 21, Dr. Carl K. Seyfert, Vanderbilt University, "The New Arthur J. Dyer Observatory."

Dallas, Tex.: Texas Astronomical Society, 8 p.m., Mercantile National Bank auditorium. May 24, Harrison Sarrafian, "Special Theory of Relativity."

Lorain, Ohio: Black River Astronomical Society, 8 p.m., Spang Bldg. May 5, E. Jennison, Warner and Swasey Co., "Telescopes."

Madison, Wis.: Madison Astronomical Society, 8 p.m., Washburn Observatory. May 12, observatory staff, "Eclipses."

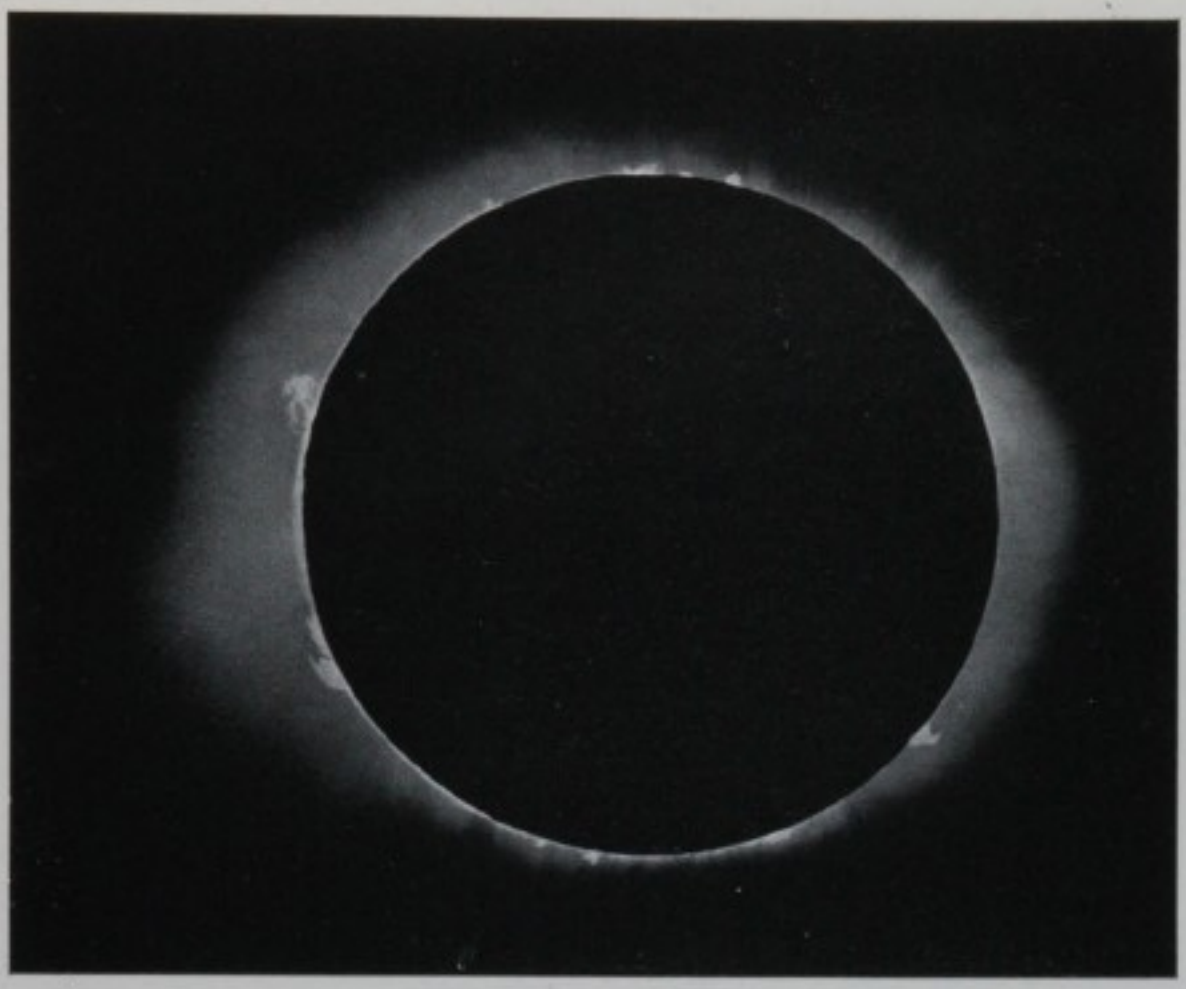
Minneapolis, Minn.: Minneapolis Astronomy Club, 7:30 p.m., Public Library. May 5, Maxine Begin, Science Museum, "Stars over Minneapolis."

New York, N. Y.: Amateur Astronomers Association, 8 p.m., American Museum of Natural History. May 19, annual meeting.

Oakland, Calif.: Eastbay Astronomical Society, 8 p.m., Chabot Observatory. May 1, W. C. Marion, University of California, "Earthquakes and the Amateur."

Sacramento, Calif.: Sacramento Valley Astronomical Society, 8 p.m., Little Theater, Sacramento Junior College. May 4, Dr. Joel Stebbins, Lick Observatory, "Pulsating Stars."

Teaneck, N. J.: Bergen County Astronomical Society, 8:30 p.m., Observatory, 107 Cranford Pl. May 12, William C. Casperson, "Meteors."



Much of the beauty of totality comes from the brilliant red hydrogen prominences that protrude past the edge of the moon and contrast strongly with the pearl gray of the inner corona. A view like this is best obtained through binoculars or with low power on a small telescope. This Lowell Observatory photograph was made at the eclipse of June 8, 1918.

Events Along the Shadow Path

By Paul W. Stevens, *Rochester Academy of Science*

PERTINENT DATA for stations along the path of totality on June 30th are given in the large table opposite; this information should be of special value to observers who wish to time the contacts accurately and to those who plan to photograph the phenomena. On pages 230 and 231 is a map of the path in that region of Minnesota, Wisconsin, and Michigan where the largest concentration of observers is expected to be.

Over the approximate range of longitude from 90° to 99°, the sun rises already partially eclipsed, so the data for first contact are omitted from the table. The easterly limit of 75° longitude for the table lies east of Hudson Bay; very few amateur or professional observers in North America will be located east of that longitude.

In Canada, there are few accessible observing points even west of 75° longitude; these are shown on the map from the **American Ephemeris** eclipse supplement* that was published in the February issue. They are located on the road and railroad near Hearst, Ontario, and on the railroad running north from Cochrane to Moosonee and Moose Factory at the foot of James Bay.

The accompanying charts are designed to aid the reader in visualizing the geometry of the situation in the sky as the moon appears to pass across the sun, as seen from points along the central line and the edges of totality, and from a short distance outside the edges.

In each chart, the larger circles represent the moon, exaggerated in size relative to the smaller circle for the sun. The parallel dashed lines indicate the moon's motion eastward across the sun. It is suggested that the reader cut out a disk of cardboard the size of the moon circle and slide it across each diagram between the dashed lines; this will give a better idea of the changing relative positions of the sun and moon than our diagrams and discussion alone can do.

In part A, the line **OV** runs from the sun's center toward the zenith, perpendicular to the horizon, while **ON** is the sun's hour circle and is perpendicular to the sun's apparent diurnal motion, neglecting the minute effect of change in declination. Accordingly, **VON** equals the angle the sun's diurnal path makes with the horizontal; its value can be found readily from the table by taking the difference between the position angles measured from the north point and from the vertex. For example, at 99° longitude, this difference is 43 degrees at second and third contacts.

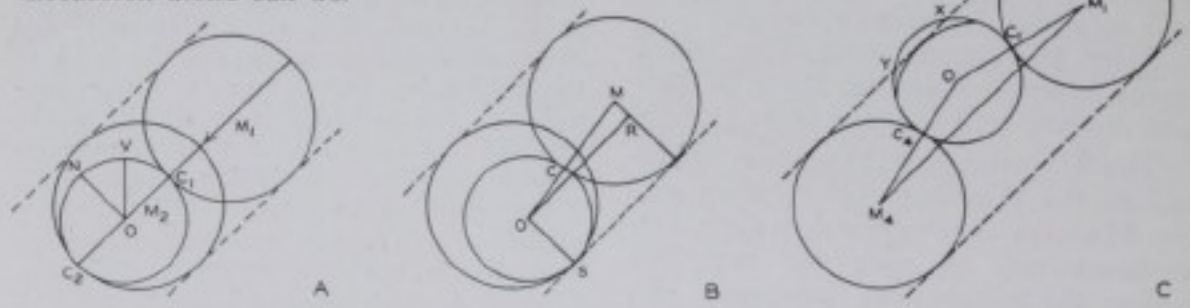
At all the stations tabulated, the sun is in the northeast quarter—its azimuth is less than 90 degrees. This has an important effect on the variation of angle **VON** during the eclipse at any station; in diagraming predicted position angles, use the large table to take into account the sun's changing azimuth, altitude, and hour angle. As an example, consider the situation at longitude 88° west:

Contact	*Angle NOC*	*Angle VOC*	*Angle VON*
First	272°	310°	38°
Second	92	134	42
Third	272	314	42
Fourth	92	138	46

The positions of the moon in A are drawn for both first and second contacts, M_1 and M_2. When the moon is at M_1, first contact takes place at C_1, and the initial partial phase of the eclipse begins. When the moon has advanced to M_2, the disks are internally tangent at C_2; the sun is completely covered and totality begins. For stations on the central line, the center of the moon appears to pass directly over the center of the sun, and the points M_1-C_1-M_2-O-C_2 lie on a straight line. The position angles of C_1 and C_2, measured from the north point, differ by 180 degrees. Similar considerations apply to third and fourth contacts, at the end of totality and the terminal partial phase, respectively.

Part B shows the situation along one edge of the path. Here totality is instantaneous, for second and third contacts coincide at **S**, corresponding to the least apparent separation between the centers of sun and moon.

There is quite a difference in the behavior of the contacts as we consider observers progressively farther from the central line toward the edges of the path. The position angle of first contact, at **C** in part B, changes only by the small angle **ROM** (which amounts to



Diagrams by the author to show sun-moon positions for observers along the central line (A); at the edge of the shadow (B), and just outside the path of totality (C).

*This booklet, **Total Eclipse of the Sun, June 30, 1954,** is issued as a supplement to the 1954 **American Ephemeris**. The supplement may be ordered from the Superintendent of Documents, Washington 25, D. C., for 40 cents (do not send stamps). The 1954 **American Ephemeris** costs $3.75.

The Path of the Total Phase in the United States and Central Canada

Longitude from Greenwich	Northern Limit	Central Line	Southern Limit	First Contact			Second Contact			Third Contact			Fourth Contact			Duration	At Mid-Totality Sun's			Shortest Distance to Edge of Path
				Universal Time	Angle East from N. Point	Angle East from Vertex	Universal Time	Angle East from N. Point	Angle East from Vertex	Universal Time	Angle East from N. Point	Angle East from Vertex	Universal Time	Angle East from N. Point	Angle East from Vertex		Altitude	Azimuth	Hour Angle	
°	° ′	° ′	° ′	h m s	°	°	h m s	°	°	h m s	°	°	h m s	°	°	s	°	°	° ′	In miles
+99	+43 00	+42 24	.. ..	.. .. ..	...	...	11 07 07	92	135	11 08 16	272	315	12 00 56	91	139	68.7	0.06	57.83	−112 56	34
98	43 28	42 52	+42 17	.. .. ..	...	...	11 07 08	92	135	11 08 18	272	315	12 01 16	91	139	69.8	0.93	58.51	111 56	34
97	43 56	43 20	42 44	.. .. ..	...	...	11 07 10	92	135	11 08 21	272	315	12 01 39	92	139	71.1	1.81	59.21	110 55	35
96	44 24	43 48	43 11	.. .. ..	...	...	11 07 15	92	135	11 08 27	272	315	12 02 04	92	139	72.3	2.68	59.91	109 54	35
95	44 53	44 16	43 39	.. .. ..	...	...	11 07 21	92	135	11 08 34	272	315	12 02 31	92	139	73.5	3.56	60.63	108 52	35
+94	+45 21	+44 44	+44 07	.. .. ..	...	...	11 07 28	92	135	11 08 43	272	315	12 03 00	92	139	74.8	4.44	61.36	−107 50	35
93	45 49	45 12	44 35	.. .. ..	...	...	11 07 39	92	135	11 08 55	272	315	12 03 31	92	139	76.1	5.31	62.11	106 47	36
92	46 18	45 40	45 02	.. .. ..	...	...	11 07 51	92	135	11 09 08	272	315	12 04 04	92	138	77.3	6.18	62.87	105 44	36
91	46 46	46 08	45 30	.. .. ..	...	...	11 08 04	92	134	11 09 23	272	315	12 04 39	92	138	78.6	7.04	63.64	104 40	37
90	47 14	46 35	45 56	.. .. ..	...	...	11 08 20	92	134	11 09 40	272	315	12 05 16	92	138	79.9	7.90	64.42	103 36	37
+89	+47 42	+47 03	+46 23	10 16 24	272	310	11 08 37	92	134	11 09 58	272	314	12 05 55	92	138	81.2	8.76	65.21	−102 32	37
88	48 10	47 30	46 50	10 16 26	272	310	11 08 56	92	134	11 10 18	272	314	12 06 36	92	138	82.5	9.62	66.02	101 27	38
87	48 37	47 57	47 17	10 16 29	272	310	11 09 16	92	134	11 10 40	272	314	12 07 18	92	137	83.9	10.47	66.85	100 22	38
86	49 04	48 24	47 44	10 16 34	272	310	11 09 39	92	134	11 11 04	272	314	12 08 02	92	137	85.2	11.32	67.69	99 16	38
85	49 31	48 50	48 10	10 16 40	272	310	11 10 03	92	134	11 11 30	272	314	12 08 48	92	137	86.5	12.16	68.55	98 10	39
+84	+49 58	+49 17	+48 36	10 16 48	272	310	11 10 29	92	134	11 11 57	272	314	12 09 35	92	137	87.8	13.00	69.42	− 97 03	39
83	50 25	49 43	49 02	10 16 57	272	310	11 10 56	92	134	11 12 25	272	314	12 10 24	92	136	89.2	13.83	70.31	95 56	39
82	50 51	50 09	49 27	10 17 08	272	310	11 11 25	92	134	11 12 55	272	314	12 11 15	92	136	90.5	14.65	71.21	94 49	40
81	51 17	50 34	49 51	10 17 20	272	310	11 11 55	92	134	11 13 27	272	314	12 12 08	92	136	91.8	15.47	72.13	93 41	40
80	51 42	50 59	50 16	10 17 34	272	310	11 12 27	92	134	11 14 00	272	313	12 13 02	93	136	93.2	16.28	73.06	92 33	40
+79	+52 07	+51 24	+50 41	10 17 49	272	310	11 13 00	92	133	11 14 35	272	313	12 13 57	93	135	94.5	17.08	74.01	− 91 25	40
78	52 32	51 49	51 06	10 18 05	273	310	11 13 35	93	133	11 15 11	272	313	12 14 53	93	135	95.8	17.87	74.98	90 16	41
77	52 56	52 13	51 30	10 18 23	273	310	11 14 11	93	133	11 15 48	273	313	12 15 50	93	135	97.1	18.66	75.96	89 07	41
76	53 20	52 37	51 53	10 18 42	273	310	11 14 48	93	133	11 16 26	273	313	12 16 48	93	134	98.4	19.45	76.95	87 57	41
75	53 44	53 00	52 16	10 19 02	273	310	11 15 26	93	133	11 17 06	273	313	12 17 48	93	134	99.7	20.22	77.96	86 47	41

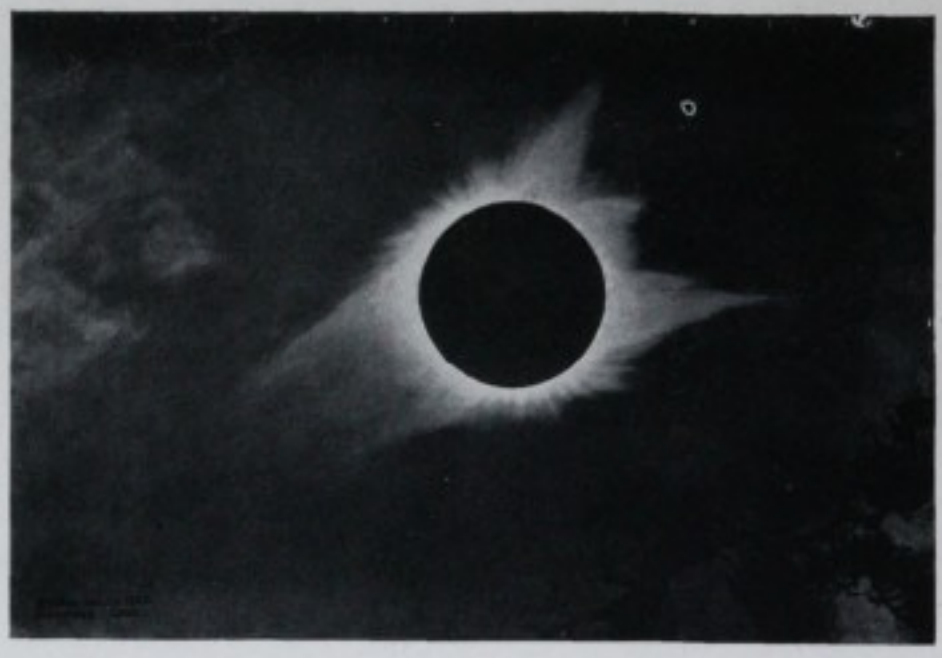
37 minutes of arc at this eclipse) from its value along the central line. For second and third contacts, however, the situation is very different, because in the short terrestrial distance between the center and edge of the path their position angles swing 90 degrees. To know the exact position angle at which totality will begin and end, an observer must know how far he is from the center line. For this eclipse, in Wisconsin and Michigan, the following approximate figures may be useful:

Distance in miles from central line	*Position angle NOC Contact II*	*Contact III*	*Duration seconds*
30 northwest	145°	219°	48
20 northwest	124	240	67
10 northwest	107	257	77
0	92	272	80
10 southeast	77	287	77
20 southeast	60	304	67
30 southeast	39	325	48

The foregoing table is based on Table VI and VII in the eclipse supplement, where far more detailed information is given, which allows an observer who knows his latitude and longitude anywhere within the path to predict the position angles of the contacts and the duration of totality. Table V there will give the contact times.

Some observers will be situated near the limits of the path and will be unable to travel to the central line. For them, distances of fractions of miles can be significant in increasing the length of observed totality. For longitudes 93° to 88° west (from Minneapolis to the Keweenaw peninsula), the first half mile inside the edge increases the duration of totality to 12 seconds. From Table VIII of the supplement, the following durations in seconds of time are taken:

Miles inside limit	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
Longitude 93° west	12	16	20	23	26	28	30	32	34	36
Longitude 88° west	12	17	21	24	27	29	32	34	36	37



Long coronal streamers and short polar spikes are typical of the shape of the corona near minimum of the sunspot cycle. The coming eclipse may resemble this one seen from the northeastern United States on January 24, 1925. This painting by Howard Russell Butler portrays the naked-eye appearance.

It is important to get several miles inside the predicted and plotted limits, however, as the exact position of the shadow edge is uncertain.

Part C of the diagram concerns observers outside but near the path of totality. The dashed lines show that the moon fails to cover that part of the sun outside the points on its limb marked **X** and **Y**. First contact is marked by C_1 and last contact by C_4; as the eclipse is partial, there are no second and third contacts. As suggested above, sliding a disk the size of the moon's circle between the parallel lines will aid in understanding what happens here.

The motion of the cusps of the solar crescent are particularly interesting just outside the edges of the path of totality. To visualize this phenomenon choose disks for the sun and moon that are nearly alike in size and slide them so they pass nearly tangent to each other. It will be seen that just as **OM** becomes perpendicular to **XY**, at the time of maximum partial eclipse, the illuminated crescent of the sun swings rapidly around the moon in a very striking manner.* Observers just outside of totality on June 30th will enjoy watching for this effect, and it can be dramatically recorded on motion pictures.

*It is this effect on which Dr. R. d'E. Atkinson bases his method of timing solar eclipses for geodetic purposes, as described by him in **Sky and Telescope**, November, 1952.

Highway Map of WISCONSIN

SPEED LAW: 65 M.P.H. DAYS 55 M.P.H. NIGHTS

SCALE OF MILES - ONE INCH EQUALS APPROXIMATELY 18 MILES

Populations of Cities and Towns

Population symbols shown as, as enclosed by ○ indicate County Seats

COMPILED BY The H. M. Gousha Company

Road Surfacing

	Numbered Thru Routes U.S.	Numbered Thru Routes State	Numbered State Routes	Other Roads
SUPER-HIGHWAYS 4 or more lanes				
PAVED ROADS Concrete, Asphalt, Surface-treated				
IMPROVED ROADS Gravel, Stone, Treated Sand-clay				
GRADED ROADS Drained and Maintained				
DIRT ROADS Unimproved				

Highway Markers

UNITED STATES 28 STATE 58 (45) COUNTY A

Mileages

MILEAGE BETWEEN TOWNS AND JUNCTIONS 3 4 4

TOTAL MILEAGE BETWEEN DOTS 35

Map Symbols

POINTS OF INTEREST

FISH HATCHERIES

AIRPORTS Principal, Others

STATE PARKS With Campsites, Without Campsites

COUNTY LINES

TIME ZONE BOUNDARY

Duluth

Superior

Two Harbors

Ashland

Minneapolis

St. Paul

Stillwater

Bayport

New Richmond

Rice Lake

Ladysmith

Eau Claire

Chippewa Falls

Mesomonie

Cambridge

Cloquet

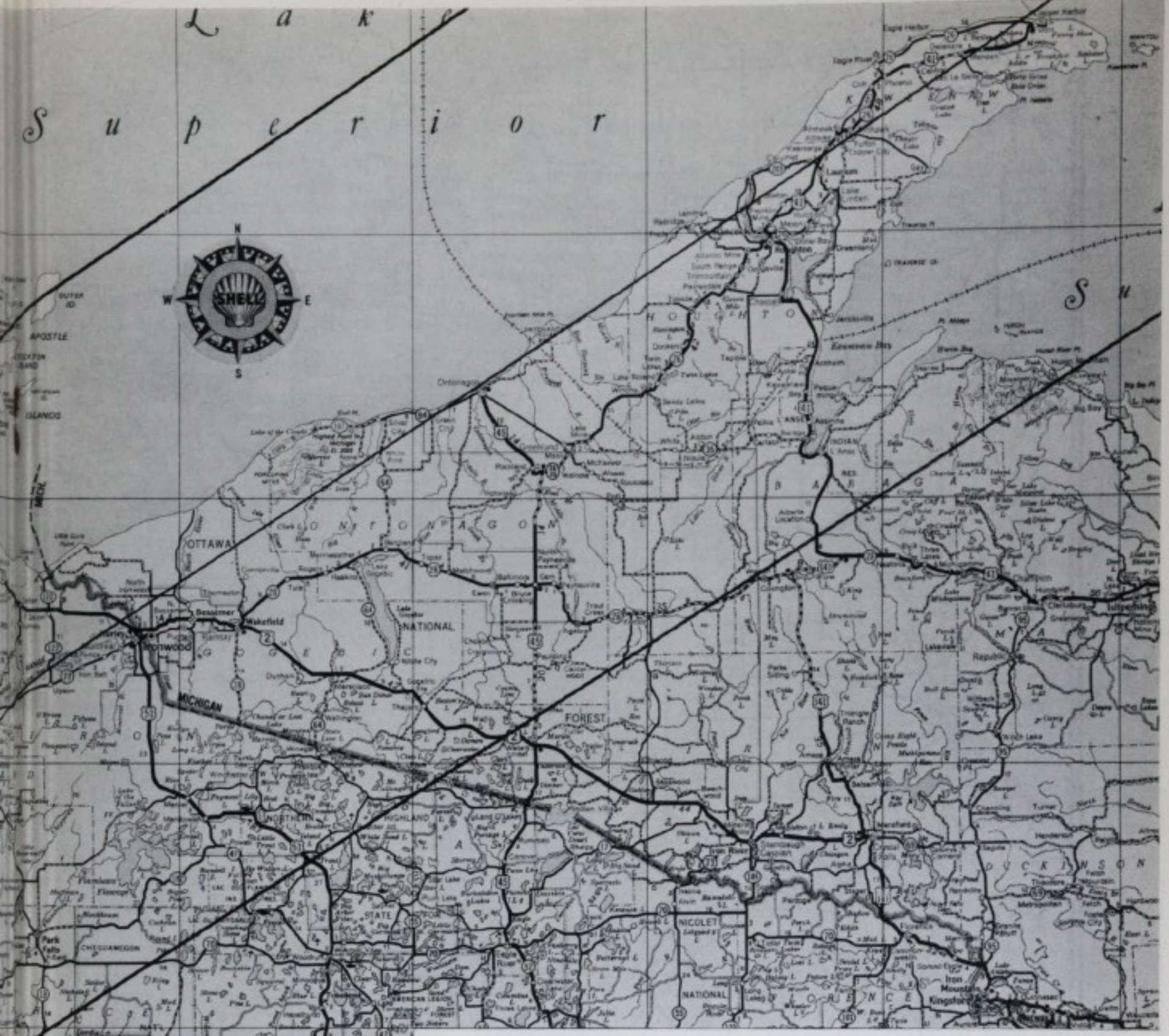
MINNESOTA

To Brainerd

To St. Cloud

To St. Cloud To St. Cloud

To Mankato



ECLIPSE ROAD MAP

THIS REGION of the north-central United States will undoubtedly attract thousands of eclipse observers from all over the country, for it is favorably situated from the standpoints of accessibility, places to stay, and general weather prospects. Early morning cloudiness is least at Minneapolis, with the chances that the eclipse will be visible decreasing by about 10 per cent from there to the tip of the Keweenaw peninsula. Further weather details are in Edward M. Brooks' article in the October, 1953, issue of **Sky and Telescope.**

At Minneapolis, the sun will be about 5½ degrees high at totality; at Copper Harbor, it will be nearly 10 degrees high. The edges of the path of the moon's umbral shadow are plotted by heavy, nearly parallel lines; the central line extends midway between them. The path increases in width from 72 miles at St. Paul to 76 miles on the peninsula. The duration of totality will be 76 seconds in the Twin Cities, and about six seconds longer at the tip of the Keweenaw peninsula. The southern shore of Lake Superior is bordered by sharply rising land, and observers can easily reach points 500 feet or more above the level of the lake, which is 602 feet above mean sea level. The highest point in Michigan is near the central line, 2,023 feet high in the Porcupine Mountains state park. This map is reproduced by courtesy of the Shell Oil Company, copyright H. M. Gousha Company.

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Astronomical Films

A number of motion pictures suitable for instructional use in astronomy are available at the present time, and we take this occasion to list the producers and titles of all those films known to the teachers' committee. Although there are many good movies on such topics as atomic energy and optics as well as on the various aspects of navigation, we confine the accompanying list to those films that are chiefly devoted to general astronomy.

Information has been taken from unpublished lists and reviews prepared by Drs. Alice Farnsworth, Freeman Miller, Marguerite Risley, and Marjorie Williams, for the teachers' committee, by Dr. C. P. Custer, of the Stockton Astronomical Society, and by E. F. Bailey for the Astronomical League, to each of whom the writer is indebted. Reference can be made to an illuminating report by Dr. Thornton Page, "Motion Pictures as an Aid in Teaching Astronomy," in *Popular Astronomy* for March, 1951.

The several producers, whose addresses are given below, can provide you with catalogues and with the names of their nearest dealers. Some of the films can be rented or purchased from your state or regional film library. The Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., sells for 15 cents a rather complete listing entitled, "A Directory of 897 16-mm. Film Libraries."

The list of titles is grouped by producer. All films are 16-mm., sound, black and white, unless otherwise noted. For those few whose subject matter is not evident from the title, a remark on content is added parenthetically after the title. Following this are the running length in minutes, notes on sound or color where necessary, educational level, and a quality indicator. Educational level is indicated by *J* for junior high school or younger, *S* for senior high school or older, and *X* where we have no information. One should note that categories *J* and *S* are not mutually exclusive, since some of the films are all right "for the whole family." The quality indicator is given only for those films that have actually been previewed by one of the above-mentioned group or by the writer. An asterisk indicates a generally favorable opinion; a dagger indicates a generally unfavorable opinion, usually because of excessive factual error or because of datedness.

A. F. Films, Inc., Room 1001, 1600 Broadway, New York 19, N. Y.
"Hermits of the Sky" (life of observers at Pic du Midi), 10 min., *S*, *.

Public Relations, California Institute of Technology, 1201 E. California St., Pasadena 4, Calif.
"The Story of Palomar," 40 min., black or color, *S*, *.

High Altitude Observatory, University of Colorado, Boulder, Colo.
"Explosions on the Sun," 12 min., silent, *S*, *.

Coronet Films, Coronet Building, Chicago 1, Ill.
"Gravity," 11 min., black or color, *J*.
"The Solar System," 11 min., black or color, *J*.

Encyclopedia Britannica Films Corp., 1150 Wilmette Ave., Wilmette, Ill.
"The Earth in Motion," 11 min., *S*, *.
"Exploring the Universe," 11 min., *S*, *.
"The Moon," 11 min., *S*, *.
"The Solar Family," 11 min., *S*, *.

Edited Pictures System, Inc., 165 W. 46 St., New York 19, N. Y.
"The Earth — Rotation and Revolution," 9 min., *J*, †.

Franco-American Audio-Visual Distribution Center, Inc., 934 Fifth Ave., New York 21, N. Y.
"Cinema et Astronomie" (eclipses of sun and moon, solar features), 25 min., sound in French, *X*, *.
"Voyage dans le Ciel" (trip through the universe), 20 min., sound in French, *X*, *.

International Screen Organization, 609 Philadelphia Ave., Washington 12, D. C.
"The Depths of Space — Exterior Galaxies," 10 min., *S*, *.
"The Milky Way," 10 min., *S*, *.
"The Moon," 10 min., *S*, *.
"The Solar System," 10 min., *S*, *.
"The Sun," 10 min., *S*, *.

Knowledge Builders, 625 Madison Ave., New York 22, N. Y.
"The Earth and Its Seasons," 10 min., *J*, *.
"Story of the Telescope," 11 min., *J*, †.
"The World We Live In," 10 min., *J*, †.

Audio-Visual Education Center, University of Michigan, Ann Arbor, Mich.
"Solar Prominences," 11 min., *S*, *.

Teaching Film Custodians, Inc., 25 W. 43 St., New York 18, N. Y.
"Exploring Space" (a rocket trip), 9 min., *J*, *.

United World Films, Inc., 1445 Park Ave., New York 29, N. Y.
"Day and Night," 9 min., black or color, *X*.
"Latitude and Longitude," 9 min., black or color, *X*.
"The Seasons," 9 min., black or color, *X*.

Young America Films, Inc., 18 E. 41 St., New York 17, N. Y.
"This Is the Moon," 11 min., *J*.
"The Sun's Family," 11 min., *J*.
"What Makes Day and Night," 11 min., *J*.

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Sky Publications

MAKING YOUR OWN TELESCOPE, by Allyn J. Thompson — This book gives complete instructions on how to make a 6-inch reflecting telescope, including the mirror and cell, tube, equatorial mounting, and tripod, with discussion of eyepieces, setting circles, and suggestions for a second telescope **$4.00**

INSIGHT INTO ASTRONOMY, by Leo Mattersdorf — A book for the layman answering the questions the average person has on astronomy **$3.50**

RELATIVITY AND ITS ASTRONOMICAL IMPLICATIONS, by Philipp Frank — The general theory of relativity discussed for the layman ..... **$.50**

SKY SETS I — 24 pictures of the solar system and galactic objects, each 8½ x 11¾ inches printed on heavy paper, with a white border. A separate sheet of captions is included **$4.00**

MOON SETS — 18 separate pictures from Lick Observatory negatives, each 8½ x 11¾ on a sheet 12 x 18 inches. Small key charts are provided for the identification of lunar seas, mountains, and craters **$3.00**

ATLAS OF THE HEAVENS — 16 charts covering the entire sky, each 18 x 24 inches, make up the Skalnate Pleso **Atlas of the Heavens**. The charts show all stars to visual magnitude 7.75, including binary and multiple stars, and variables. All galaxies brighter than 13.0 are included, as well as clusters and nebulae, and Milky Way outlines **$6.00**

MAPPA COELESTIS NOVA — A map of the northern sky, 25 inches in diameter. Six colors are used to indicate the spectral types of all stars brighter than the 5th magnitude. The map shows the magnitude of each star, as well as the names of the brighter ones. A decorative display piece **$5.00**

WORLD-WIDE PLANISPHERE, by William H. Barton, Jr. — A book of basic constellation charts and masks to show the stars above the horizon at any time of night or year, at all latitudes, northern and southern **$3.00**

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BOOKS AND THE SKY

AMATEUR TELESCOPE MAKING, BOOK THREE

Albert G. Ingalls, editor. Scientific American, Inc., New York, 1953. 644 pages. $7.00.

THIS new book will be welcomed by all amateurs, as well as those who have moved forward to become professional astronomers or opticians. It is dedicated to the late Russell W. Porter, who will long be remembered as the inspiration for **Amateur Telescope Making** and **Amateur Telescope Making Advanced.** This new member of the **A.T.M.** family will appeal mostly to the advanced amateur, although any person willing to devote time and study to it will receive valuable information and new ideas.

The 44 chapters, written by men of outstanding reputation, contain such a wealth of material that only some of the highlights can be mentioned here. Among these are two very interesting optical systems for astronomical photography, described by James G. Baker, with complete design and construction data. One is a 3-inch Cooke triplet objective for photography. The other is a corrector plate for reflectors (see "The New Arthur J. Dyer Observatory," **Sky and Telescope,** January, 1954). Consisting partly of an achromatic lens, the corrector plate transforms the original instrument into a wide-angle flat-field camera, with performance equaling that of a Schmidt.

Another modern development in reflectors is the Maksutov telescope. Franklin B. Wright describes the construction of a Maksutov-type simple diverging meniscus that serves as a correcting lens for Newtonian and Herschelian telescopes; his example contains only spherical optical surfaces.

Earle B. Brown tells us how to construct an aluminizer, a project I attempted myself several years ago. If this information had been available then many of my difficulties could have been avoided. The article gives full details and lists firms who can supply the materials needed. Many drawings and photographs explain trouble-saving methods.

"The Theory and Application of the Concave Diffraction Grating" is by C. Fred Clarke, a person in the "know-how" class. The making of a very instructive spectrograph arrangement is told in simple language. It uses a grating with a focal length of 106 centimeters, and it is built on a 53-inch lathe bed. Another laboratory-type grating spectrograph with a five-foot focal length is described by Strathmore R. B. Cooke and Robert A. Wilson. Both accounts are detailed, with many illustrations. Such instruments can be bought on the open market, but at prices outside the average amateur's budget.

How to make flats that are really flat is told by R. E. English, an amateur years ago who is now a professional. Can you imagine an optical surface accurate to one five-millionth of an inch? We have his word for it and he can back it up. His article makes certain that the reader understands all the operations. He gives valuable pointers on the pitch and the proper hardness for it, the size and weight of the tool, and how to reduce zones that are concave or convex. This article alone is worth the price of the book, offering a golden opportunity to any person who is willing to get started in making flats. This would make a wonderful project for an amateur group. Flats are being used more each day to replace prisms in certain optical instruments.

We all recall the name of Fred B. Ferson, who so generously assisted Uncle Sam during World War II by his ability to perfect Amici roof prisms, which were so much in demand. He and Peter Lenart,

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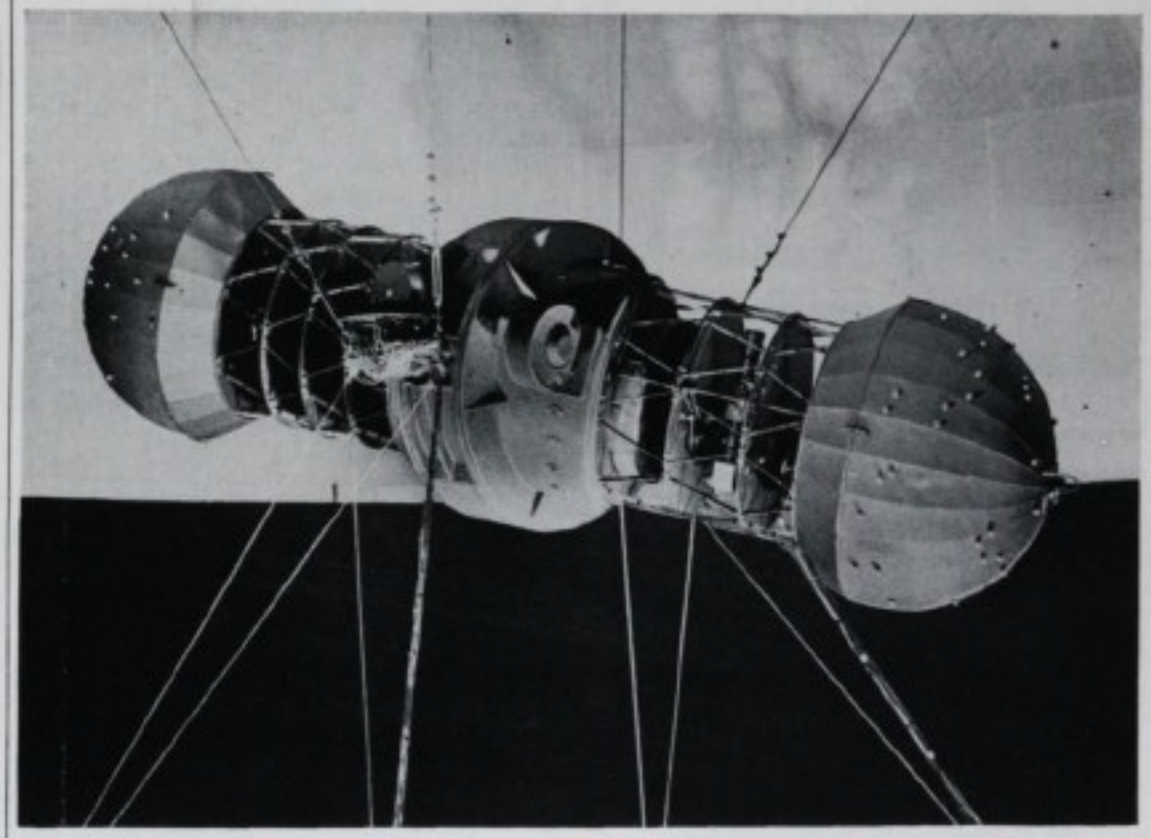

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Jr., write on the production of lenses, from a one-piece affair such as an amateur might make in a hobby shop to what professional shop men fabricate on a production basis, taking into consideration not only precision but also general operational costs. Drawings, photographs, and sketches in this article will greatly assist those for whom lens work is a new undertaking. The full explanations are based upon the more recent methods, and include some brand-new tests. Ferson's rise from amateur to advanced and then into business proves that opportunities are always present, if one can recognize them.

Irvine C. Gardner gives us directions for constructing an optical spherometer for measuring strong curves on small lenses like those used in eyepieces. In another chapter, Horace H. Selby clearly explains the functions and designs of eyepieces. He gives a set of diagrams of 91 telescopic eyepiece systems, and for 39 of these he tabulates specifications.

The G-sum method for designing telescope objectives is described by Alan E. Gee, and here the reader will refer to his algebra. While his method goes into more detail than those by Ellison and Haviland (in earlier books of the **A.T.M.** family), it allows control of both spherical aberration and coma. With little more trouble, we can have the assurance of making a better objective. Designing an objective lens with ray tracing methods is described by James H. Wyld. He removes the deep-rooted fear of formulas and leads the tyro by the hand, explaining every detail in simple language, and presenting sample work sheets.

Hitherto, literature on binocular construction and testing has been rare. We are now given first-hand information by G. Dallas Hanna, whose group in World War II was assigned by the U. S. Navy the reconditioning of 6,000 pairs of binoculars. His clear account tells us practically everything that is to be known about these instruments.

Hanna contributes another article on the separation of grits, whose tendency to form into small lumps causes much trouble in mirror and lens making; this method removes that enemy known to all of us as "scratchitis." He says, "We use our abrasive alongside roughing mills and never take any precautions such as taking a bath before fine grinding, yet it has been so long since any of us has had scratches on glass that we have forgotten." To do the trick Hanna describes, you need only a glass funnel, a large bottle, a tray to catch overflow, some glass tubing, and a solution of water glass.

C. R. Hartshorn's account of the Barlow lens should create much enthusiasm. Most of us have looked into an eyepiece when a Barlow lens was inserted between it and the objective or diagonal, and have realized that the combination is far superior to the simple ocular alone. Complete instructions are given, so that the average amateur will not find it too difficult to construct and assemble a Barlow. These lenses can be bought commercially, but designing and making the lens yourself

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UNITRON

Chicago, Ill., March, 1954: The Burnham Astronomical Society attracted large numbers of interested visitors to its booth at the Hobby Show held in the Coliseum. Chicagoans welcomed this opportunity to learn more about Astronomy, which is one of today's fastest growing hobbies.

In this photo, UNITRON owner Willard E. Robinson shows his 3-inch Altazimuth Refractor to the Rev. Baxter Mow and to Frank Goodwin, vice-president of the Society and manufacturer of the Goodwin Resolving Power Lens.

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will materially reduce the cost and will give you the satisfaction of personal accomplishment. I highly recommend this chapter and hope that many will follow its directions.

The construction of two amplifiers for use with a stellar photoelectric photometer is described in much detail by Gerald E. Kron. One is battery-operated and the other uses house-lighting current. Making an inexpensive photometer is also explained.

No fewer than seven articles deal with various aspects of Schmidt cameras. There is a noteworthy contribution by Henry E. Paul on their design and construction, which includes a valuable method for testing deep spheres. Six chapters are reprints of standard articles, of which one is a translation of Bernhard Schmidt's own classic paper of 1931-32. Another is Paul G. Hodges' biographical account of Schmidt, which is enjoyable reading. This gifted and eccentric man, who had only one hand, worked always in a cutaway coat and striped trousers. His method of grinding and polishing the correcting plate was the work of a genius.

Mirror makers will be interested in Irvin H. Schroader's account of the caustic test, which can be applied to short-focus and aspheric mirrors, and is sensitive to 1/100 wave length. This method, a refinement and modification of the familiar Foucault knife-edge test, utilizes the generally overlooked fact that center of curvature of an off-axis area of a paraboloid does not lie on the axis, but on the caustic curve.

Another chapter by Selby is entitled, "Optical Bench Testing." This should aid greatly that person desiring to construct this piece of equipment for his own particular use. It is highly recommended for a shop project, as an optical bench is constantly needed for testing lenses for systems which the average amateur desires to make. The bench affords a means for putting those lenses to work, instead of cluttering up the storage compartments in the shop.

James W. Shean leads us into another field that will be new to many. Ever try to make a lens usable for photography? Here is where the reader gets the inside dope on elementary camera lenses.

At the close of the book, six pages in Albert G. Ingalls' editor's chapter describe various kinds of optical glasses and give detailed hints on how to procure optical glass from the manufacturers. This chapter also carries short biographies of the contributors, with photographs of many of them; this will in a way make us feel more closely related to one another.

Amateur Telescope Making, Book Three covers too much ground for any one reader to master, and consequently no one can turn to it without finding something new. The book is in easy-to-read language, and the mathematics in it will not deter anyone interested in optical work. This valuable reference should be on the bookshelf of every optical shop, from the amateur's cellar workbench to professional establishments.

LEO N. SCHOENIG
Amateur Astronomers Association
Pittsburgh, Pa.

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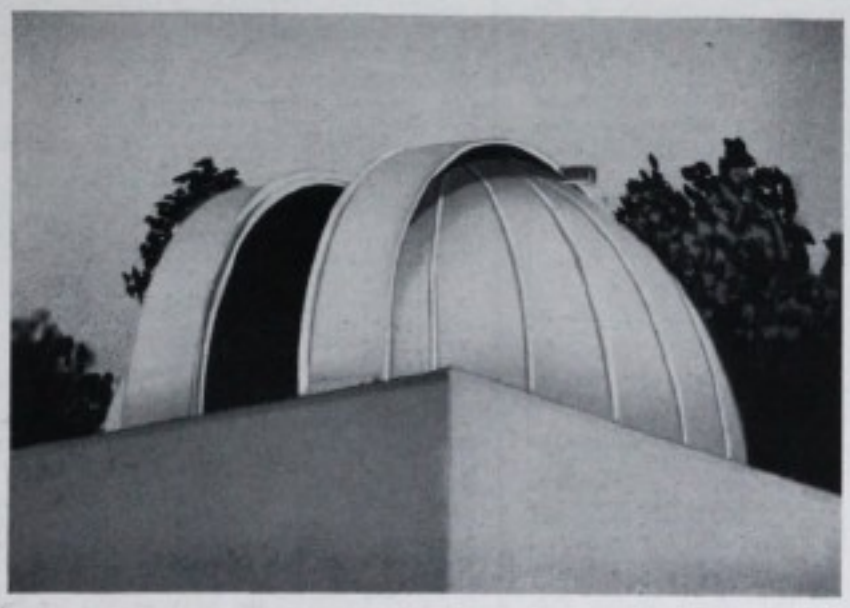

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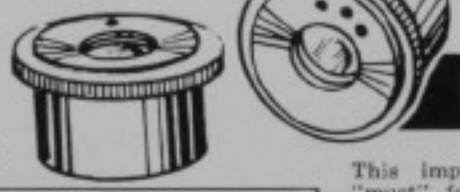

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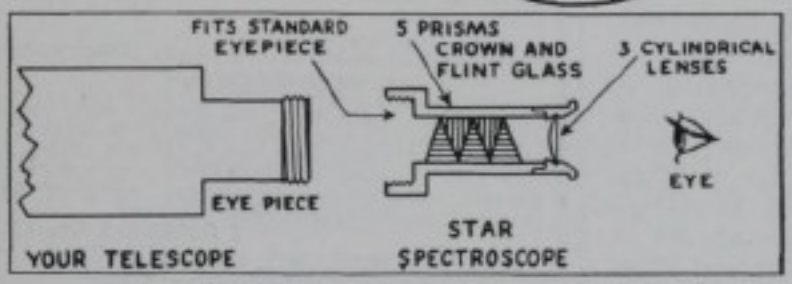

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A 32-page book included free of extra cost. Contains valuable information about the stars, provides easy identification of the constellations.

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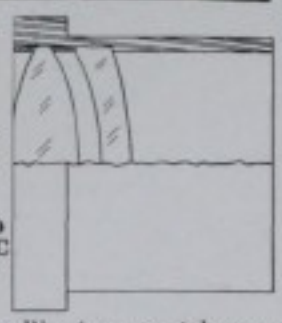

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Notes on Basic Optics — VII

MOST of the elementary aspects of our topic have been covered, and we are ready to go on to what many readers may consider more interesting matters. Coming installments will discuss the synthesis of optical systems, and show how the reader may apply the facts disclosed in earlier sections to plan an optical system for a specific useful purpose. After that, we will learn why lenses, prisms, and mirrors possess the properties they do, and will discuss optical aberrations and the actual design of the optical components themselves.

Before we do so, however, it will be worth while to consider a few terms and concepts that we will be using.

H. Some Matters of Terminology

1. **Relative aperture** (also known as **aperture ratio** or **focal ratio**). A very convenient term is relative aperture. It tells us whether a lens is weak or strong, is likely to give us trouble with aberrations or not, is going to be complex and expensive or simple and cheap; whether it will require special design or if any available lens will do the job, and often whether or not the design is outside reasonable bounds.

The relative aperture of a lens or mirror is defined as the aperture (or entrance pupil, for an optical system) expressed as a fraction of the effective focal length. It is written as a fraction, for example, f/3.5, f/12. In the first case, the aperture is 1/3.5 of the focal length, in the second case it is 1/12 of the focal length.

The f/number, which may be used to describe the same characteristic of the lens, is the denominator of the fraction that expresses the relative aperture. Thus, the two lenses just mentioned have f/numbers of 3.5 and 12, respectively.

Often a lens with a large relative aperture (small f/number) is called a fast lens; one with a small relative aperture is a slow lens. This idea of the speed arises from consideration of camera lenses: small f/numbers permit short exposures, hence such lenses are fast; larger f/numbers require longer exposures.

This can be seen by considering a lens that forms an image of an infinitely distant object of appreciable angular extent. The size of the image is determined by the focal length. Suppose the relative aperture of a lens is f/6; then the aperture which collects light from each object point has an area of $\pi d^2/4$, where $d = f/6$, and f is the effective focal length. Hence the light-gathering area is $\pi f^2/144$.

Suppose we increase the relative aperture to f/3, keeping the focal length the same. The new aperture will gather more light, but the image size will remain the same; therefore, the image is brighter than before. Since d becomes f/3, the light-gathering area is $\pi f^2/36$, or four times the previous value. Thus, only one quarter of the previous exposure will be required; that is, an f/3 lens is four times as fast as the f/6 lens.

The iris diaphragm of a camera is provided to permit changing the relative aperture, and the diaphragm control is marked accordingly. It is common practice with cameras to mark the relative apertures (stops) in numbers that increase by factors of the square root of 2. If this is done, the exposure between any two stops is either halved or doubled, depending on whether the aperture is increased or reduced.

In recent years, there has been a tendency toward the setting of camera apertures in terms of "T" stops. These allow for the lack of complete transmission of light by the lens (which in a complex camera system may be significant) and thus yield numbers more accurately commensurate with the required exposures.

Phrases like "an f/3 lens" or "this lens is made to work at f/5" are useful, for they tell the reader in a general way much about the lens, in terms of complexity of

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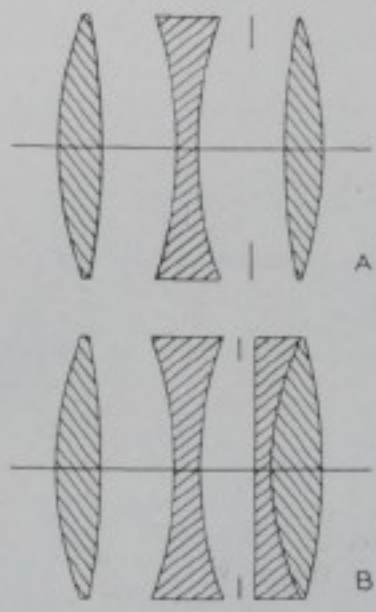
design, number of individual components, aberrational performance, cost, space requirements, and the like. The effect of relative aperture on these characteristics



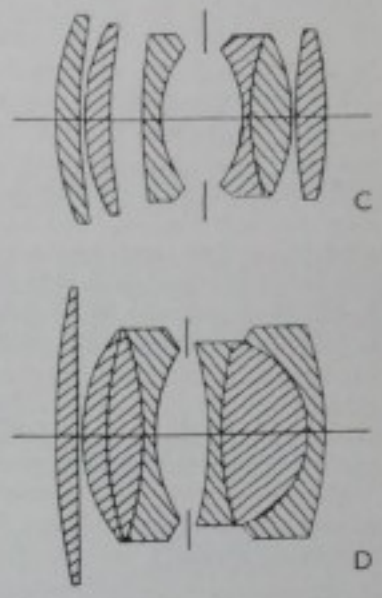


Fig. 24. In these diagrams, crown glass is indicated by hatching from upper left to lower right; flint glass, lower left to upper right. Light enters from the left in each case. Four camera lens systems are shown, A: Cooke triplet; B: Tessar; C: Ultron; and D: Sonnar.

can probably best be visualized by a look at some camera lenses. Such lenses must be well corrected, of course, to render a sharp image on a flat focal plane.

Even a simple pinhole will give a fairly sharp image if its relative aperture is of the order of f/300. A single positive meniscus lens works quite well in box cameras (although not perfectly, by any means) at about f/16. The three-element Cooke triplet (Fig. 24A) is used at relative apertures up to about f/5.

The Tessar (Fig. 24B), a modified triplet with a doublet rear element, by Rudolph, is satisfactory at f/3.5. In Fig. 24, C and D, examples of an excellent f/2 lens, the Ultron by Tronnier, and an f/1.5 lens, the Sonnar by Bertele, indicate the number and form of the components required to maintain image quality with these large aperture ratios.

Telescope objectives need not cover such large fields of view as camera lenses. A simple doublet objective will give almost perfect imagery at f/15; for small telescopes such as finders, binoculars, and sighting scopes, doublet objectives are quite satisfactory at f/8, and in many instances may be acceptable up to f/4. The amateur telescope maker well knows that at ratios longer than f/10 a 6-inch mirror need not be parabolized; a spherical mirror is equivalent to a single positive lens.

Wide-field eyepieces can be designed to give good performance at f/6; for a more restricted field, as in rifle scopes, the aperture may be increased to f/4 without significant loss of quality.

In the case of microscopes, a slightly different measure is used: **numerical aperture.** Two factors make the change necessary. Microscopes do not work at infinite object distances, and often they make use of immersion objectives, where the space between the specimen and objective is filled with a liquid of rather high refractive index. The numerical aperture is defined as $n \sin \theta$, where n is the refractive index of the immersion medium (unity for air), and θ is the half angle of the aperture as seen from the specimen.

For all practical purposes, we may consider that the numerical aperture is the reciprocal of twice the f/number. Microscope objectives with a numerical aperture of 0.25 (f/number = 2) are relatively simple, usually consisting of a pair of

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achromatic doublets. For larger numerical apertures the construction becomes more complex. Dry objectives cannot have numerical apertures greater than unity, since θ cannot exceed 90°, but numerical apertures of 1.2 and greater occur in immersion objectives.

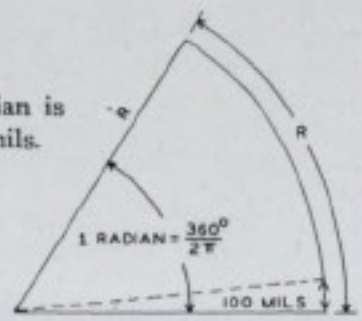
2. The **diopter system** is sometimes convenient when we deal with the relation of optical instruments to the eye, but this system should be avoided at other times. The diopter is a measure of the **power** of a lens. Since power is proportional to the reciprocal of the focal length, short focal length means a strong lens, long focal length a weak one. A lens with a focal length of one meter has a power of one diopter; one with ½-meter focal length has a power of two diopters, and so on.

Eyepieces of instruments often have a focusing scale marked in diopters. If the eyepiece is set at zero, this means that the final image that is viewed by the eye is located at infinity; when set at −2, the eyepiece forms a virtual image ½ meter in front of the eyepiece; when set at +2, the eyepiece forms a real image ½ meter behind the eyepiece.

The relaxed normal human eye is focused for infinity. To focus on an object at 10 inches, the near point of the normal young adult, requires a change in accommodation of 4 diopters. Defects in an optical system that require changes in accommodation of ½ or even 1 diopter are not usually considered serious. This is the normal criterion in establishing tolerances on the performance of visual instruments.

3. The **mil system** of angle measurement is often very useful, especially in approximate calculations, for it allows

The radian is 1,000 mils.



problems to be worked out without resort to tables of trigonometrical functions.

If an arc of a circle is equal in length to the radius, it will subtend a definite angle, the same for all circles regardless of size. This angle is called a radian, and it is approximately equal to 206,265 seconds of arc, 3,438 minutes of arc, or 57.3 degrees. Since the circumference of a circle is equal to $2\pi r$, there are 2π radians in 360 degrees.

One mil, defined as 1/1,000 radian, is equal to 3.438 minutes of arc; and 17.45 mils equal one degree. It is obvious that the angle subtended by any object of size **d**, seen from a distance **r**, is simply **d/r** radians or 1,000 **d/r** mils. This is, of course, true only for angles sufficiently small that the length of the arc is not measurably different from that of the chord. This relation is very closely correct for angles smaller than about 50 mils, and is only ½ per cent in error for angles as large as 350 mils, or 20 degrees.

(To be continued)

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OBSERVER'S PAGE

Universal time is used unless otherwise noted.

An Introduction to Observing Saturn — I

SATURN, as seen during its current opposition by anyone lucky enough to have access to a fair-sized telescope, presents one of the most striking sights in the heavens. It is a spectacle that has inspired many of the astronomically uninitiated to become better acquainted with the whole of the known planetary system.

While an interesting view of Saturn may be obtained with a refractor as small as two inches aperture at only 25 or 50 power, at least a 3- or 4-inch telescope, preferably with powers of about 150 to 225, is needed to reveal some of the finer detail. Such a telescope shows a globe, somewhat flattened at its poles, shining with a yellowish light. On one half of the disk can be noted a prominent lighter equatorial zone, bordered by a darker belt; parallel to this are other half-visible belts, which may perhaps be traced up to the more dusky polar area. The other half of the planet's disk is crossed by the feature that makes Saturn unique—the famous rings. At the present opposition of the planet, a small telescope will show that the two concentric rings are divided by a very dark narrow line, called Cassini's division after its discoverer, J. D. Cassini.

The tilt of the rings changes from year to year, as the planet gradually swings one pole toward us, then the other, so that in turn the northern face of the rings is well exposed and then the southern face. Midway between these extremes the rings appear edge on, and because of their extreme thinness become briefly invisible in even large telescopes. When nearly edge on, the rings can be seen as a luminous line, extending on either side of the planet. The complete cycle of these changes is nearly 30 years, the period of Saturn's revolution around the sun, during which the rings appear edge on twice. The last such occasion was in September, 1950. At the present opposition of Saturn it is the north side of the rings that we see, and they will continue to open until 1958.

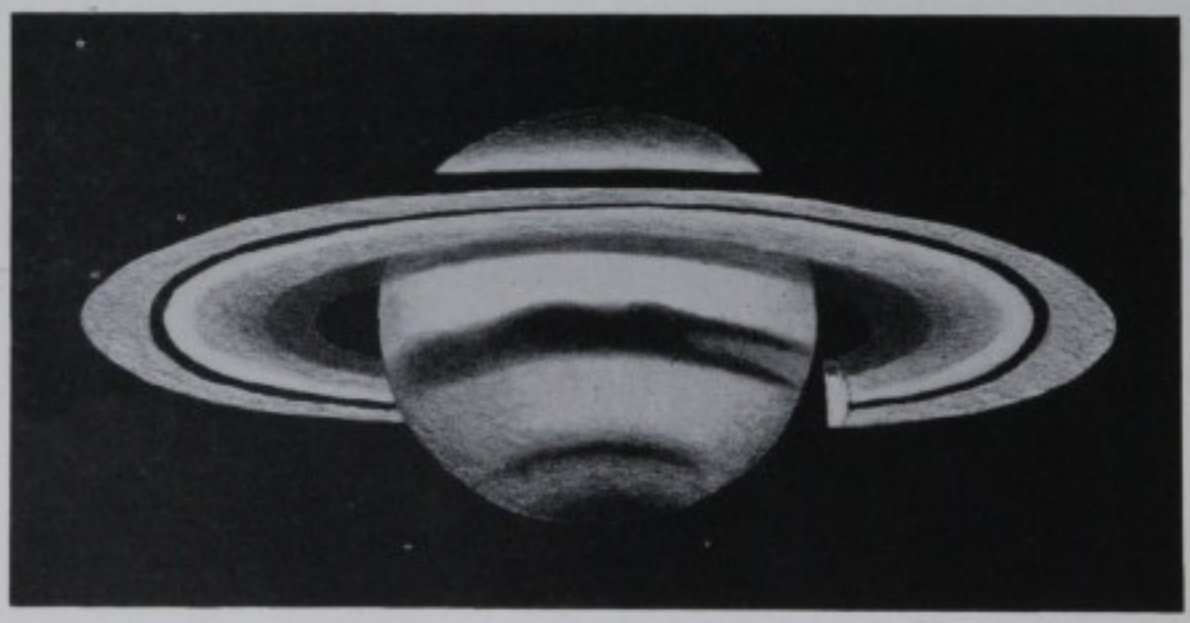
Opposition of Saturn occurs on April 26, 1954, on May 9, 1955, and about a fortnight later in each succeeding year.

Small telescopes will show several of Saturn's satellites. The largest, Titan, can be readily seen in a 2-inch, and

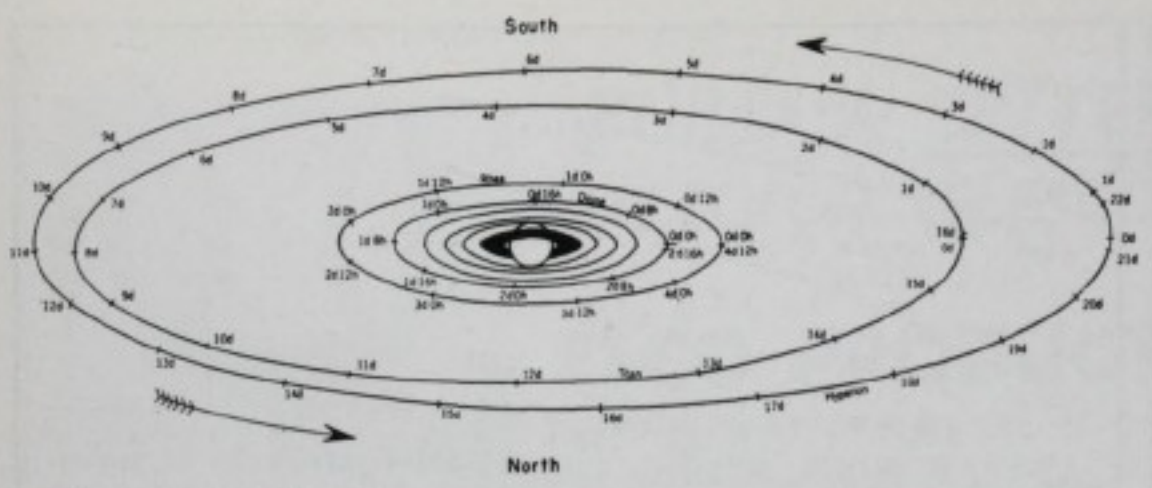
NUMERICAL DATA FOR SATURN

Mean distance from sun	887 million miles
Sidereal period of revolution around sun	29.46 years
Average orbital velocity	6.0 miles per second
Angular diameter (equatorial)	14″.9 to 20″.6
Equatorial diameter	74,200 miles
Polar diameter	66,400 miles
Volume (earth = 1)	736
Mass (earth = 1)	95
Average density (earth = 1)	0.13
Surface gravity (earth = 1)	1.17
Velocity of escape at surface	22 miles per second
Magnitude	+1.1 to −0.4
Reflecting power (albedo)	0.42
Rotation period (equatorial)	$10^h\ 14^m$
Number of satellites	9
Outside diameter of ring system	171,000 miles
Width of ring A	10,000 miles
Width of Cassini's division	3,000 miles
Width of ring B	16,000 miles
Width of crape ring	11,500 miles

(Data chiefly from Russell, Dugan and Stewart, *Astronomy*, Vol. I, 2nd edition)



The varied wealth of Saturnian detail that a moderate-sized telescope will reveal in good seeing is shown by D. P. Avigliano's drawing, made in June, 1953, with an 8-inch reflector and a power of 261. South is at the top. The prominent dark equatorial belt is double in part, and a north temperate belt is seen. Note the Terby white spot on the ring, next to the planet's shadow.



The apparent orbits of the seven inner satellites of Saturn in 1954, as seen in an inverting telescope. The positions of some satellites are indicated at stated intervals after eastern elongation, which occurs as follows: Enceladus, May 1, 12h; Tethys, May 1, 20h; Dione, May 1, 1h; Rhea, May 5, 11h; Titan, May 11, 0h. For later elongations, add multiples of the synodic period. From the "American Ephemeris and Nautical Almanac."

Satellite	*Name*	*Mean distance miles*	*Synodic period of revolution* days	hours	*Diam., miles*	*Mean mag.*
I	Mimas	115,400	0	22.6	370	12.1
II	Enceladus	148,000	1	08.9	460	11.7
III	Tethys	183,200	1	21.3	750	10.6
IV	Dione	234,700	2	17.7	900	10.7
V	Rhea	327,800	4	12.5	1150	10.0
VI	Titan	759,900	15	23.3	3550	8.3
VII	Hyperion	922,000	21	07.6	.....	15
VIII	Iapetus	2,213,000	79	22.1	.....	10.8
IX	Phoebe	8,044,000	523	15.6	.....	14

Iapetus is visible in a 3-inch. With a 4-inch glass we may be able to pick up Rhea, Tethys, and Dione as well. The **American Ephemeris** each year prints data for identifying these objects. The more minute of the satellites must be left to larger instruments. At the times when the rings are nearly edge on, satellite phenomena such as transits, occultations, and eclipses occur, but they are less striking than the corresponding behavior of Jupiter's moons.

On turning a good telescope of six to 12 inches aperture on Saturn, an experienced observer can hope to detect many additional details. For general work, he will usually employ 225x to 300x with such a telescope, and even higher powers for minute details of the ring system. I find that 250x to 300x on my excellent 8-inch reflector generally gives the best views of the delicate globe shadings, while 400x or more is best for the rings, if seeing permits these higher powers.

In telescopes like these, the darker equatorial belt may show condensations, and it is often seen double. One or more belts may be seen in the temperate zones, and the polar shadings will be apparent. When the rings are suitably tilted, their very dark shadow on Saturn is quite striking. Occasionally, lighter spots appear on the planet, such as the very prominent white spot seen in the equatorial zone in 1933. Some observers have detected a small whitish cap at the pole of the planet; wisps between the belts, much like those that appear on Jupiter, have been seen, as well as a very delicate equatorial band. But the amateur must be warned that details such as the last three are quite difficult, and require the combination of an experienced observer, excellent seeing, and a flawless instrument.

The observer using a fair-sized telescope on Saturn should be on the alert for the appearance of spots that can be used to time the rotation of the planet. In the equatorial zone the rotation period is about 10 hours 14 minutes, and somewhat longer in temperate latitudes. The uncertainty arises from the great rarity of prominent spots or disturbances. Attempts to time the rotation of the more delicate markings are usually doomed to failure due to their transitory nature. The possibility of finding a conspicuous, long-lived spot is a strong incentive to the advanced amateur to maintain a systematic program of observations of the ringed planet.

(To be continued)

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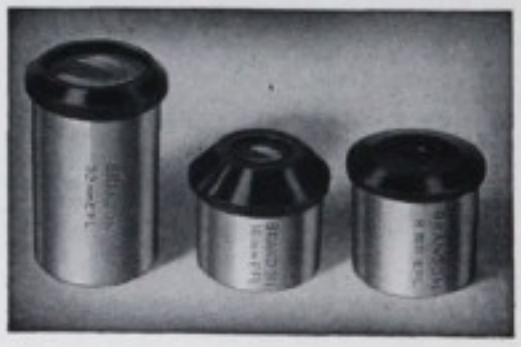
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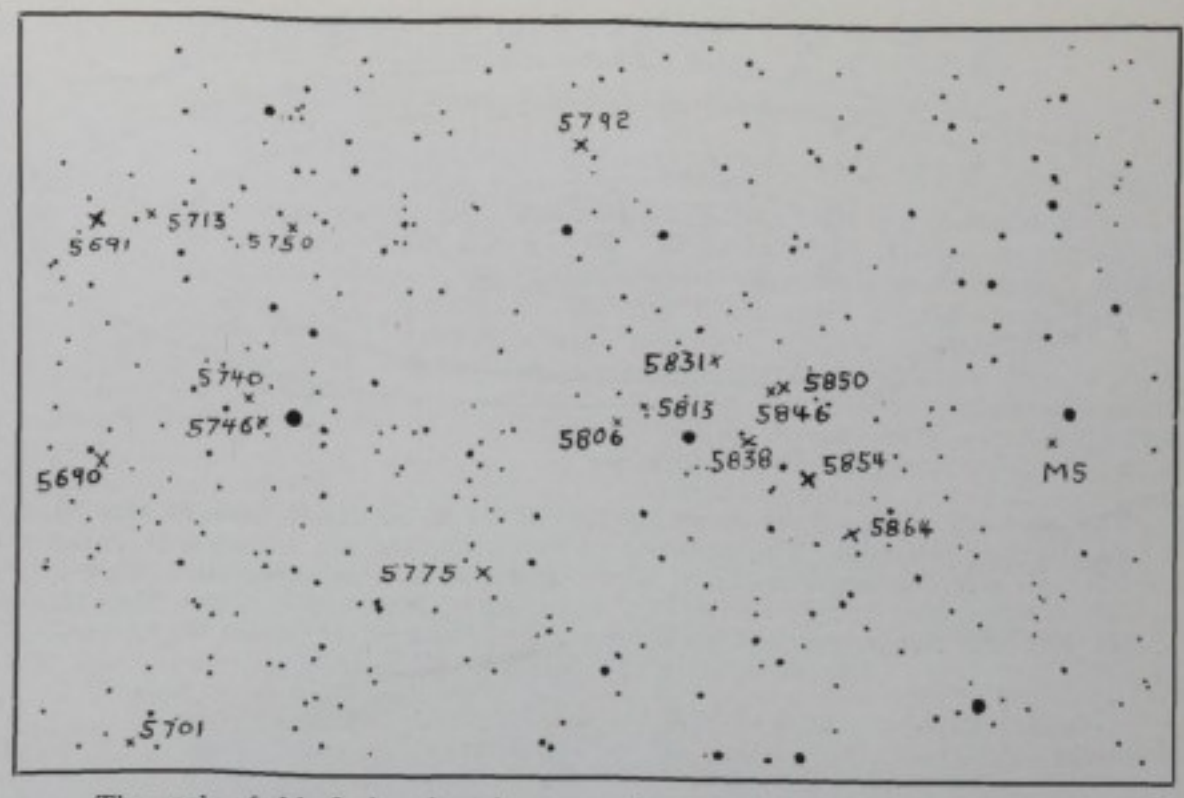

The scale of this finder chart is one centimeter to one degree. South is at the top, east to the right. The faintest stars shown are 9th magnitude.

DEEP-SKY WONDERS

OVER at the eastern edge of Virgo, near the splendid globular cluster M5, lies a little grouping of external galaxies. This is the last concentration of the host of such objects that dominate the spring skies. As many amateur observers favor area charts, these galaxies are amassed on one map and the data for them is presented in tabular form.

The types **E, S, SB** mean elliptical, spiral, and barred spiral, respectively, as assigned by Shapley and Ames. **Sa, Sb, Sc** indicate tightly, moderately, and loosely wound spirals, and : denotes uncertainty in assignment of type or magnitude.

Herschel's descriptions, given in the notes, use the abbreviations: **B**, bright; **F**, faint; **v**, very; **p**, pretty; **c**, considerably.

The remaining notes, giving date and instrument, are from my files. It will be noted that Herschel's descriptions do not agree too well with Shapley's photographic magnitudes, and I will be interested to hear from amateurs who can make their own visual magnitude comparisons of these objects.

WALTER SCOTT HOUSTON

NGC	*R.A.* (1950) h	m	*Dec.* °	′	*Mag.*	*Size* ′	′	*Type*	*Notes*
5690	14	35.2	+2	30	12.9	2.6	x 0.5	S:	vF; 16-inch, 1947
5691		35.3	−0	11	13.0				pB; easy, 16-inch, 1947
5701		36.7	+5	34	12.8	1.5		SBa	cB; not seen, 10-inch, 1944
5713		37.6	−0	05	11.8	2.1	x 2.1	Sb	cB; easy, 4-inch, 1942
5740		41.9	+1	54	12.8	3.0	x 2.0	Sb	pB; easy, 11-inch, 1948
5746		42.3	+2	10	11.8	7.4	x 0.8	Sb	B; easy, 6-inch, 1953
5750		43.6	−0	01	12.6	1.4	x 0.9	Sb	pF; not seen, 8-inch, 1944
5775		51.5	+3	45	12.4	4.2	x 0.8	S	F; not seen, 16-inch, 1948
5792		55.8	−0	54	12.9:	5.0	x 1.7	S	pB; 10-inch, 1937
5806		57.5	+2	05	12.5	2.0	x 1.0	Sb	cB
5813		58.7	+1	54	12.2	1.4	x 1.4	E	B; easy, 6-inch, 1950
5831	15	01.6	+1	24	12.7	0.5	x 0.5	E:	pB
5838		02.9	+2	18	12.1	1.6		S	pB
5846		04.0	+1	48	11.6	1.0	x 1.0	E	vB; excellent, 4-inch, 1935
5850		04.6	+1	44	12.9	2.6	x 2.1	SB	cF
5854		05.3	+2	45	12.7	2.2	x 0.4	S:	pB
5864		07.0	+3	14	12.8	2.0	x 0.3	S:	pF; not seen, 10-inch, 1944
5904		16.0	+2	16	7.0	20			Globular cluster M5

UNIVERSAL TIME (UT)

TIMES used on the Observer's Page are Greenwich civil or Universal time, unless otherwise noted. This is 24-hour time, from midnight to midnight; times greater than 12:00 are p.m. Subtract the following hours to convert to standard times in the United States: EST, 5; CST, 6; MST, 7; PST, 8. If necessary, add 24 hours to the UT before subtracting, and the result is your standard time on the day preceding the Greenwich date shown.

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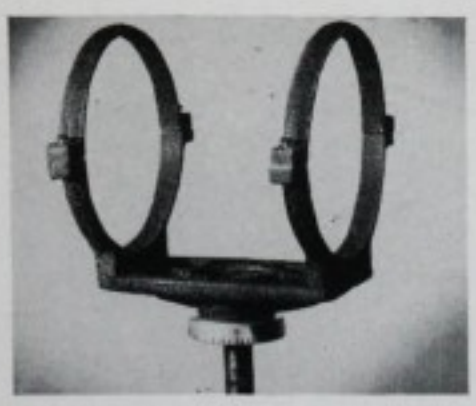

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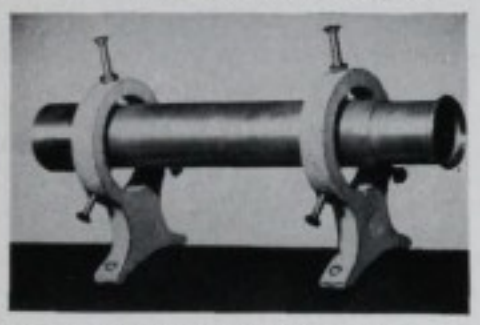

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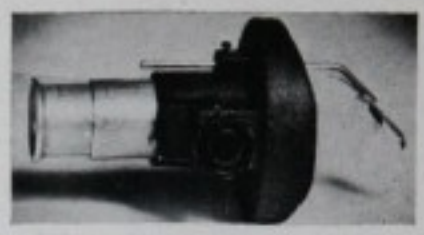

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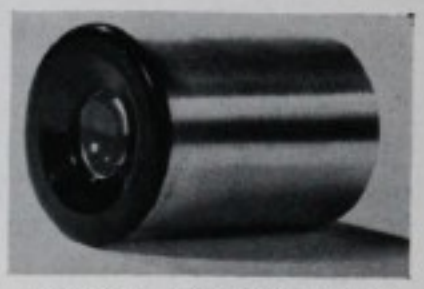

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VARIABLE STAR MAXIMA

May 2, RT Hydrae, 082**405**, 7.6; 14, R Serpentis, 154615, 6.8; 17, T Ursae Majoris, 123160, 7.9; 17, T Aquarii, 204**405**, 7.9; 20, R Carinae, 092**962**, 4.6. June 7, RU Cygni, 213753, 8.0; 9, R Ophiuchi, 170**215**, 7.6.

These predictions of variable star maxima are by the AAVSO. Only stars are included whose mean maximum magnitudes are brighter than magnitude 8.0. Some, but not all of them, are nearly as bright as maximum two or three weeks before and after the dates for maximum. The data given include, in order, the day of the month near which the maximum should occur, the star name, the star designation number, which gives the rough right ascension (first four figures) and declination (bold face if southern), and the predicted magnitude.

MINIMA OF ALGOL

May 3, 14:38; 6, 11:27; 9, 8:16; 12, 5:05; 15, 1:54; 17, 22:43; 20, 19:32; 23, 16:21; 26, 13:10; 29, 9:59. June 1, 6:48; 4, 3:36; 7, 0:45.

These minima predictions for Algol are based on the formula in the **1953 International Supplement** of the *Cracow Observatory*. The times given are geocentric; they can be compared directly with observation.

PREDICTIONS OF BRIGHT MINOR PLANET POSITIONS

Desiderata, 344, 9.4. May 18, 17:33.2 −37-08; 28, 17:26.6 −40-32. June 7, 17:15.9 −43-43; 17, 17:02.8 −46-20; 27, 16:50.4 −48-14. July 7, 16:41.0 −49-26.

Eunomia, 15, 9.0. May 18, 18:02.8 −33-06; 28, 17:55.4 −32-59. June 7, 17:45.9 −32-41; 17, 17:35.3 −32-11; 27, 17:24.7 −31-27. July 7, 17:15.3 −30-37.

Flora, 8, 9.3. May 28, 18:13.7 −18-46. June 7, 18:05.0 −19-01; 17, 17:54.3 −19-21; 27, 17:42.9 −19-43. July 7, 17:32.3 −20-07; 17, 17:23.5 −20-32.

Laetitia, 39, 9.5. May 28, 18:09.5 −8-24. June 7, 18:02.5 −8-10; 17, 17:54.2 −8-08; 27, 17:45.6 −8-18. July 7, 17:37.4 −8-42; 17, 17:30.6 −9-18.

After the asteroid's name are its number and the magnitude expected at opposition. At 16-day intervals are given its right ascension and declination (1954.0) for 0^h Universal time. In each case the motion of the asteroid is retrograde. Data are supplied by the IAU Minor Planet Center at the University of Cincinnati Observatory.

OCCULTATION PREDICTIONS

May 9-10 **Omicron Leonis** 3.8, 9:38.7 +10-06.2, 7, Im: **A** 4:22.3 −0.4 −1.4 86; **B** 4:17.6 −0.5 −1.4 83; **C** 4:25.3 −0.5 −1.5 96; **D** 4:16.9 −0.7 −1.5 91; **E** 4:14.0 −0.9 −1.7 109; **F** 4:25.7 −0.7 −2.2 134; **H** 3:56.7 −0.5 −3.1 164.

May 24-25 **Theta Aquarii** 4.3, 22:14.4 −8-00.8, 23, Im: **I** 11:07.1 −1.3 +1.2 106.

For stations in the United States and Canada, usually for stars of magnitude 5.0 or brighter, data from the **American Ephemeris** and the **British Nautical Almanac** are given here, as follows: evening-morning date, star name, magnitude, right ascension in hours and minutes, declination in degrees and minutes, moon's age in days, immersion or emersion; standard station designation, UT, **a** and **b** quantities in minutes, position angle on the moon's limb; the same data for each standard station westward.

The **a** and **b** quantities tabulated in each case are variations of standard-station predicted times per degree of longitude and of latitude, respectively, enabling computation of fairly accurate times for one's local station (long. **Lo**, lat. **L**) within 200 or 300 miles of a standard station (long. **LoS**, lat. **LS**). Multiply **a** by the difference in longitude (**Lo** — **LoS**), and multiply **b** by the difference in latitude (**L** — **LS**), with due regard to arithmetic signs, and add both results to (or subtract from, as the case may be) the standard-station predicted time to obtain time at the local station. Then convert the Universal time to your standard time.

Longitudes and latitudes of standard stations are:

A	+72°.5,	+42°.5	**E**	+91°.0,	+40°.0
B	+73°.6,	+45°.5	**F**	+98°.0,	+31°.0
C	+77°.1,	+38°.9	**G**	Discontinued	
D	+79°.4,	+43°.7	**H**	+120°.0,	+36°.0
			I	+123°.1,	+49°.5

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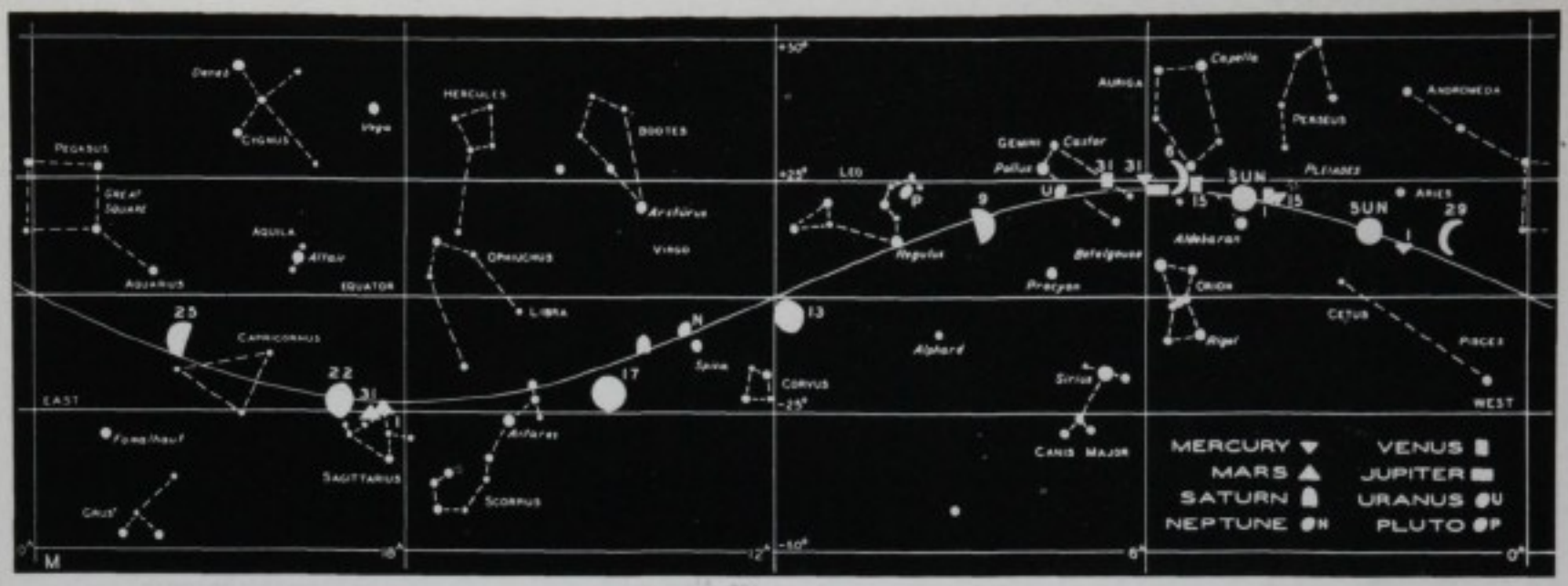

THE SUN, MOON, AND PLANETS THIS MONTH

The sun, on the ecliptic, is shown for the beginning and end of the month. The moon's symbols give its phase roughly, with the date marked alongside. Each planet is located for the middle of the month and for other dates shown.

Mercury enters the evening sky on May 8th, and will be visible to the naked eye about two weeks later. By the 20th, the planet sets one hour after the sun, appearing at magnitude −1.0. On the 31st, Mercury will remain above the horizon 1¾ hours after sunset, but it will have faded a full magnitude.

Venus appears brilliant in the western sky after sunset. On May 1st, it is located between the Pleiades and the Hyades, moving into Gemini by the end of the month. On the 15th, Venus is of magnitude −3.4, and its disk is 89 per cent illuminated.

Mars will be of major interest during the next few months, as opposition occurs on June 24th. Retrograde motion commences on May 23rd, when the ruddy planet is situated in Sagittarius, at 25° south declination. Due to its southerly position, Mars will rise 2½ hours after sunset from north temperate latitudes. The brightness of the planet increases noticeably during May, from magnitude −0.7 to −1.6. The Martian disk will be 17″ in diameter on the 23rd, a fine object for a moderate-sized telescope.

Jupiter, crossing from Taurus into Gemini, sets as twilight ends by the close of May. Two planetary conjunctions may be observed this month; on the 23rd Jupiter passes 1° 30′ south of Venus, and on the 31st, 2° 14′ south of Mercury. Jupiter, with an equatorial diameter of 33″, is magnitude −1.5 in mid-month.

Saturn may be viewed in the eastern sky after sunset as a starlike object of magnitude +0.4. Visible the entire night, the planet will be in retrograde motion near Kappa Virginis. In mid-May the ring system will be inclined 17°.2 to our line of sight, with a longest diameter of 42″.4. The planet's disk will be the same size as Mars', 17″ in polar diameter.

Uranus, a 6th-magnitude object, is low in the western sky for several hours after sunset. It is moving eastward about 2° east of Delta Geminorum.

Neptune can be located with the aid of binoculars till early morning hours. This distant planet is moving slowly eastward, about 3½° northeast of Spica in Virgo. Late in May, Neptune will be about ½° south of the variable star S Virginis. E. O.

SUNSPOT NUMBERS

American numbers for February, communicated by the AAVSO Solar Division, were zero on all dates except Feb. 8, 3; 9, 6. Provisional Zurich numbers, sent by Dr. M. Waldmeier, were zero on every date in February except Feb. 28, 7. Monthly means for February: 0.3 American; 0.2 Zurich.

Definitive monthly means for 1953 have been reported by Zurich: Jan., 26.5; Feb., 3.9; Mar., 10.0; Apr., 27.8; May, 12.5; June, 21.8; July, 8.6; Aug., 23.5; Sept., 19.3; Oct., 8.2; Nov., 1.6; Dec., 2.5. Yearly mean: 13.9.

MOON PHASES AND DISTANCE

New moon	May	2, 20:22
First quarter	May	9, 18:17
Full moon	May	17, 21:47
Last quarter	May	25, 13:49
New moon	June	1, 4:03

	May		Distance	Diameter
Perigee	2,	7h	222,200 mi.	33′ 24″
Apogee	15,	2h	252,300 mi.	29′ 26″
Perigee	30,	13h	224,200 mi.	33′ 07″
	June			
Apogee	11,	15h	251,800 mi.	29′ 30″

MAY METEORS

Conditions for observing the Eta Aquarid meteors will be favorable this year. The moon will be absent from the early morning sky when these meteors are visible. They will be most numerous before dawn on May 4th, when the predicted rate is 10 meteors per hour. E. O.

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50—Moon near Copernicus
51—Mars (in red and blue)
52—Jupiter (in blue)
53—Saturn (in blue)
54—Local galaxy (Cassiopeia) NGC 147
55—Spiral nebula (Triangulum) NGC 598
56—Spiral nebula (Camelopardalis) NGC 2403
57—Spiral nebula (Coma Berenices) NGC 4565
58—Barred spiral (Eridanus) NGC 1300
59—Barred spiral (Pegasus) NGC 7741
60—Planetary nebula (Gemini) NGC 2392
61—Hercules cluster, NGC 6205
62—Four nebulae in Leo, NGC 3185-87-90-93
63—Globular nebula (Virgo) NGC 4486
64—Globular cluster (Canes Ven.) NGC 5272
65—Lagoon nebula (Sagittarius) NGC 6523
66—Omega nebula (Sagittarius) NGC 6618
67—Nebula (Scutum) in red, NGC 6611
68—Nebulosity (Monoceros) in red, south outer region of NGC 2264
69—Cluster of nebulae (Coma Berenices), 80 million light-years distant
70—Cluster of nebulae (Corona Borealis), 240 million light-years distant
71—Cluster of nebulae (Hydra), 720 million light-years distant
72—Faint field of nebulae (Coma Berenices), one to two billion light-years distant

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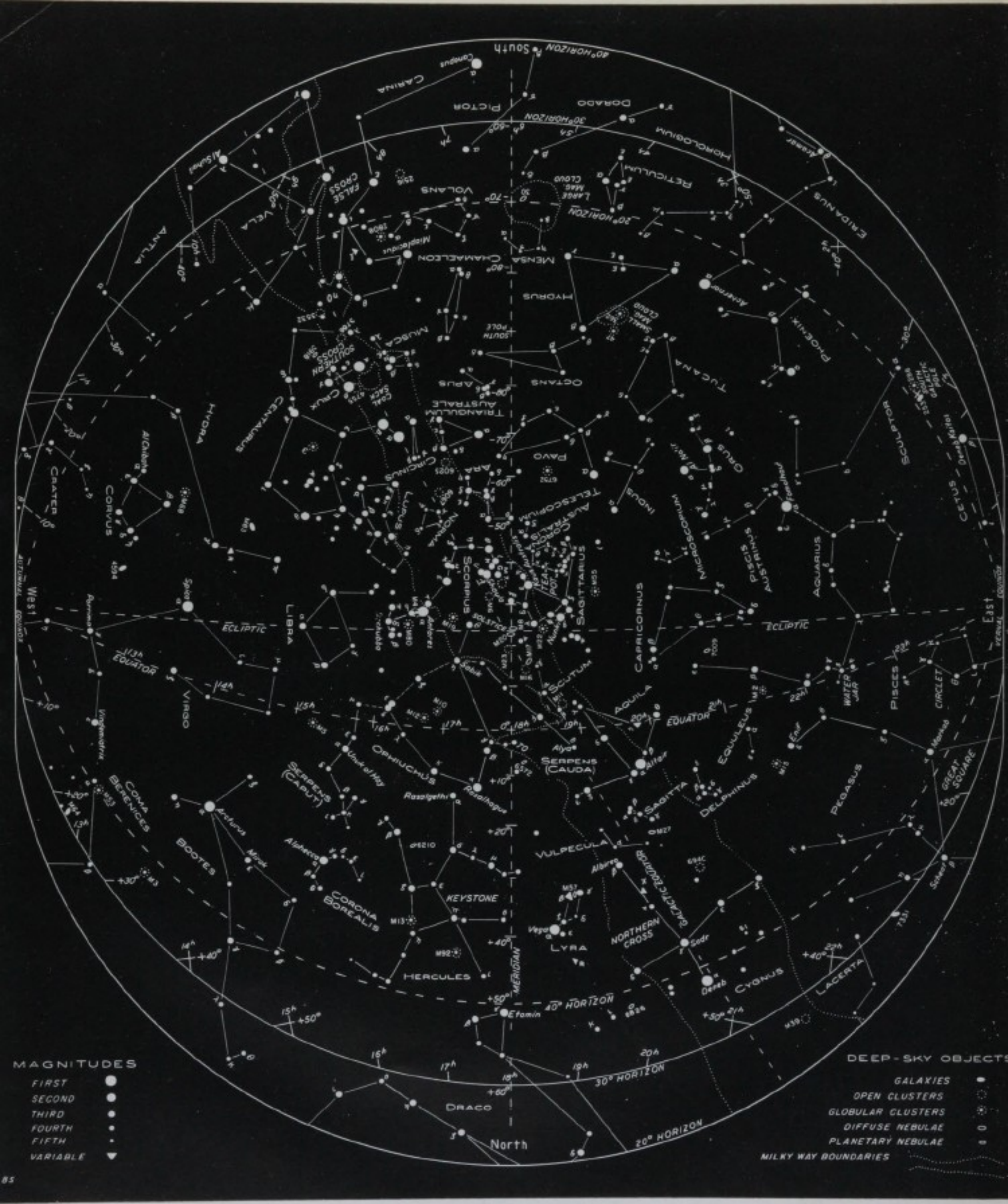
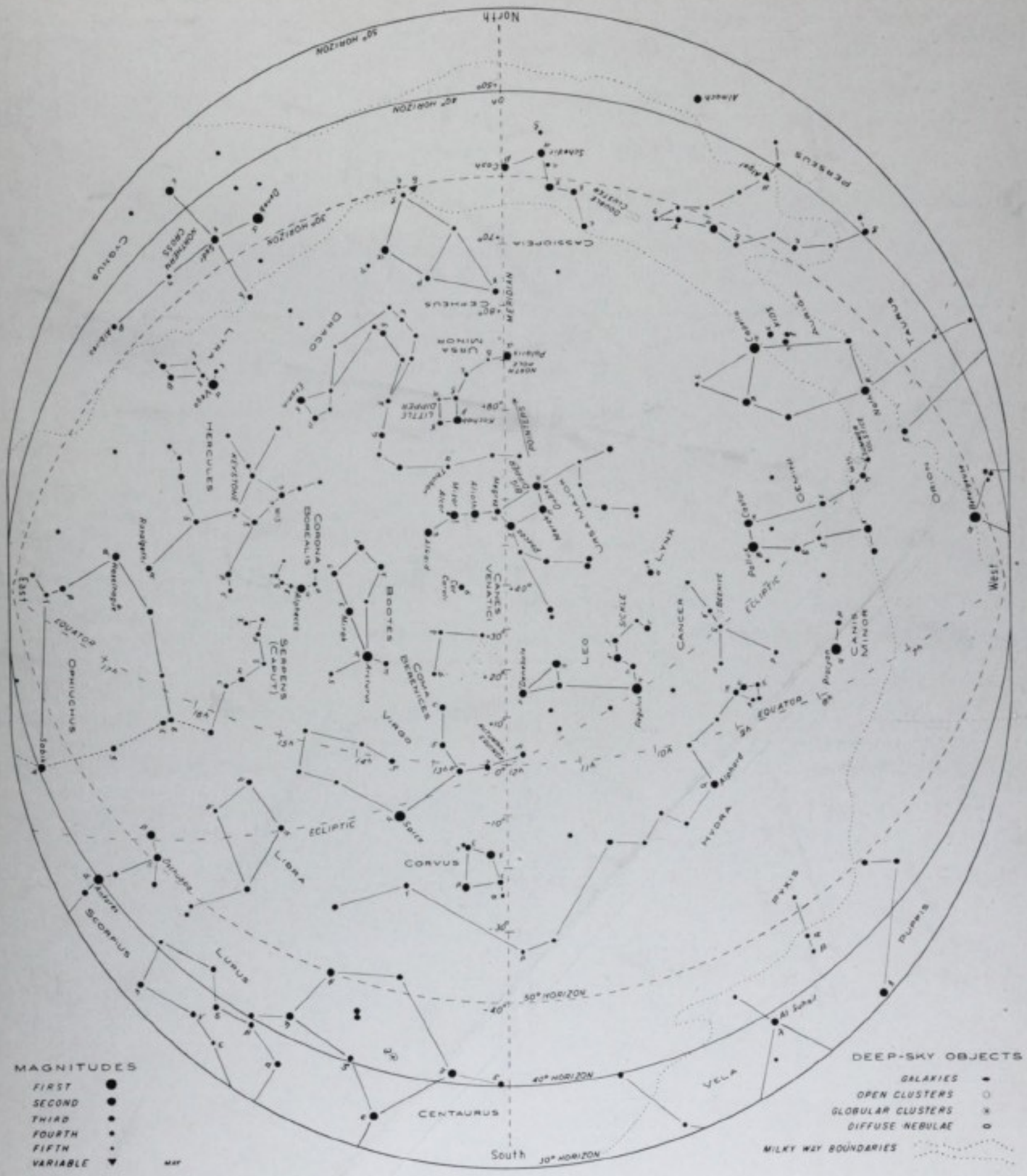


SOUTHERN STARS

The sky as seen from latitudes 20° to 40° south, at 9 p.m. and 8 p.m., local time, on the 7th and 23rd of August, respectively; also, at 7 p.m. and 6 p.m. on September 7th and 23rd. For other times, add or subtract ½ hour per week. When facing south, hold "South" at the bottom; turn the chart correspondingly for other directions. Celestial hour circles and parallels are represented as parts of circles.



The sky as seen from latitudes 30° to 50° north, at 9 p.m. and 8 p.m., local time, on the 7th and 23rd of May, respectively.

STARS FOR MAY

THE HEIGHT OF SPRING in the Northern Hemisphere is marked by the appearance of the constellation Virgo near the meridian in the early evening.

Spica, dominating this constellation, is a bluish-white star of magnitude 1.2, whose spectral type B1 corresponds to a surface temperature of 22,500° on the absolute centigrade scale. It is also an eclipsing variable star, the brightest in the sky, but the light changes are too minute to be recognized visually.

Gamma Virginis, or Porrima, one of the most famous visual double stars, was discovered in 1718; it can be divided in even small telescopes. This binary, whose period is about 180 years, was the second for which an orbit was computed. The successful prediction that the components would become too close for the largest existing telescopes to separate them (which occurred in 1836) gave the first clear demonstration that the law of gravitation applies unchanged outside the solar system.

Corvus is just approaching the meridian at our chart times. May is a good month to study the Crow, as he perches on the back of Hydra and rides across the southern sky. Corvus can be used as a pointer to the Southern Cross—a line bisecting the figure and extending southward will lead to Crux, above the horizon for observers south of latitude 27° north.

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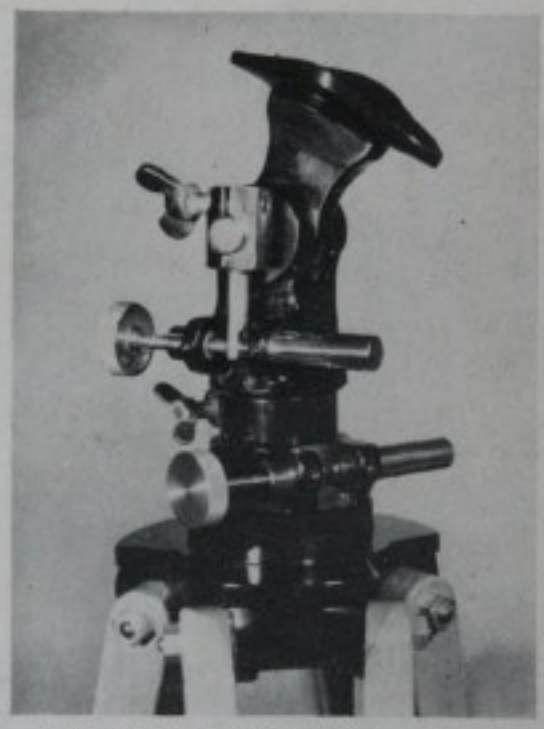

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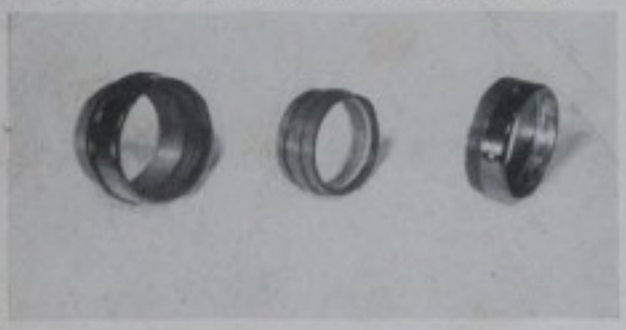

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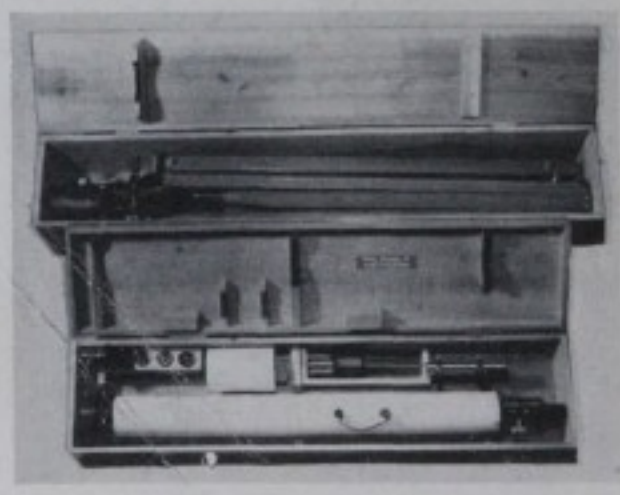

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